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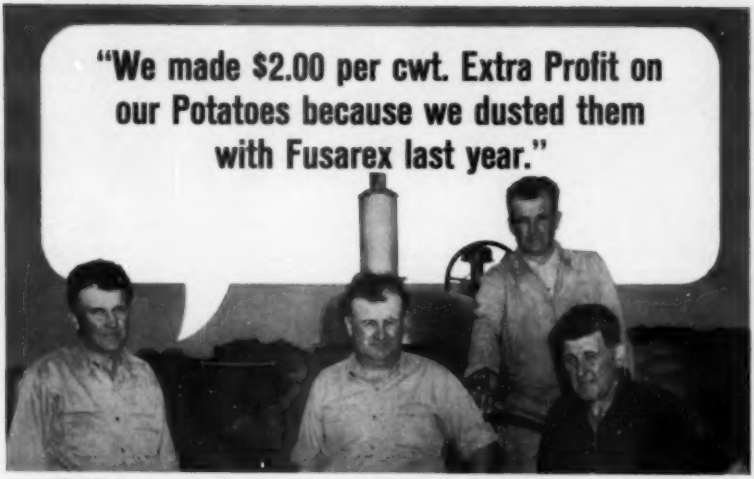

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PHYSIOLOGICAL AND ANATOMICAL CHARACTERISTICS OF SPINDLING-SPROUTED POTATO TUBERS[1]

L. F. LIPPERT[2]

Spindling sprout of potato tubers has been reported from many of the potato-producing countries of the world. This widespread occurrence has stimulated considerable investigation concerning causal factors, characteristics of abnormal tubers, and methods of detection and control. It is now generally accepted that spindling sprout is not a separate disease nor a disease symptom related to a single cause, but is more logically the expression of an abnormal physiological condition within the tuber attributable to a number of causes.

Spindling-sprouted tubers are characterized by elongated weak sprouts, measuring 1-2 mm in diameter, with the diameter uniform over the entire sprout length. Normal, weak and extreme spindling sprouts may occur on the same tuber, with the weakest sprouts generally at the stem end. Abnormal tubers have been reported to be flaccid or spongy at harvest (2, 15), and to exhibit stem end browning or necrosis, both of which aid diagnosis either at harvest or later in storage (10). These symptoms are not evident in spindling-sprouted tubers from California, so that only by sprouting in storage can the presence of the tuber disorder be verified.

Limited studies have been conducted on the physiology of spindling-sprouted tubers. Parris and Jones (12) reported increased levels of soluble solids, reducing sugars, sucrose, and nitrogen components in spindling-sprouted as compared with normal tubers. Increased total and reducing sugars were characteristic of spindling-sprouted tubers in Minnesota (5) and California (19).

Anatomical studies in Europe indicated that vascular regions of the bud primordia of eyes from spindling-sprouted tubers were definitely underdeveloped (17) and callose plugs were present in phloem sieve tubes (18), both features being absent in normally-sprouted tubers.

This investigation was undertaken to examine certain organic components and anatomical features within the tuber which might relate to cause or effect of spindling sprout, and to evaluate rapid mechanical and chemical tests for detection of spindling-sprouted tubers.

MATERIALS AND METHODS

Tubers used for these studies were collected from commercial crops in storage and from field plants artifically graft-inoculated with the aster yellows virus (8). Where possible, tubers of both White Rose and Russet Burbank varieties were sampled from the same growing area.

Growth regulator studies.—The characteristic weak and elongated sprout growth and early sprouting of spindling-sprouted tubers suggest

[1]Accepted for publication April 28, 1960. Portion of a thesis presented in partial fulfillment of requirements for the Ph.D. degree, University of California, Davis, Calif.

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the influence of growth regulators. Growth promoting and inhibiting substances were assayed by the combined paper chromatography-Avena coleoptile straight growth technique (11). Cylindrical cores were removed from eye regions of spindling- and normal-sprouted tubers of both varieties to provide duplicate 4 g samples. Growth substances were extracted with diethyl ether and concentrated under reduced pressure as described by Nitsch (11). The final residue was taken up in 1 ml isopropanol and spotted on Whatman #1 paper for development in isopropanol : ammonia : water solvent (8:1:1 v/v) by descending chromatography. All chromatograms were examined under ultraviolet light for the presence of fluorescent compounds, and one portion of the paper examined colorimetrically for growth regulators by spraying with a solution of 5% perchloric acid-0.05 M ferric chloride (50 : 1 v/v).

The test strip for each extract was cut from the chromatogram and sectioned into twenty 1 cm segments for Avena coleoptile assay. Subapical 4 mm segments of oat coleoptiles of the Ventura variety were obtained from 3 mm below the tip. Five segments selected at random were incubated for 18-20 hours at 25° C. with each 1 cm section of the test chromatogram in 1 ml of 2% sucrose-buffer solution (11). Twenty coleoptiles incubated in sucrose-buffer solution with a section of the chromatogram devoid of test extract served as controls.

Coleoptile growth was measured to the nearest 0.1 mm under a 10× binocular microscope equipped with a plastic rule taped to the stage. Growth was converted to percentage increase or decrease compared to the mean growth of 20 control coleoptiles. These data were analyzed for statistical significance.

Organic acid studies.—The organic acid composition of spindling- and normal-sprouted tubers was determined qualitatively in three separate samples of White Rose and Russet Burbank tubers, first as crude tissue extracts spotted on filter paper and chromatographed, and later as semi-purified organic acids prepared by passing extracts through anion and cation resin exchange columns followed by paper chromatography examination.

Twenty-gram samples were prepared from approximately 100 tuber discs obtained from eye tissue of normal and abnormal tubers. Aqueous extracts were passed through Dowex 1X-8 anion and Duolite C-3 cation resin exchange columns as described by Resnik *et al.* (14).

Fifty ul aliquots of the acid solutions were spotted on No. 1 paper along with known organic acids observed in the crude assays. Papers containing extracts and control acids were developed by descending chromatography for 20-25 hours in n-amyl alcohol saturated with 5 M formic acid (1 : 1 v/v). Chromatograms were sprayed with 1% bromphenyl blue indicator to locate organic acids as yellow spots on a blue background. Identification of the organic acids was based on comparisons of Rf values published by Lugg and Overall (9).

Chlorogenic acid content.—Chlorogenic acid determinations were conducted on 2 separate groups of White Rose and Russet Burbank tubers. Tissue plugs from eye and non-eye areas of the tuber were removed with a 7 mm diameter cork borer. Uniform 2 mm thick layers including the periderm and outer cortical tissue were cut from the plugs and designated

as periderm sample. The next lower 4 mm tissue region was marked cortex sample. Sprouts from the 2 tuber types were also analyzed.

Tissue samples were extracted in 95% ethanol for 6 weeks at 0° C. An aliquot equivalent to 1.0 g fresh weight tissue was removed from each alcohol extract, reduced to dryness, and the residue dissolved in 10 ml of 10% isopropanol. One ml of the isopropanol extract was reacted with 3 ml each of 0.5 N HCl, Arnow's reagent (1) and 1.0 N NaOH. Pink color was read in a Bausch and Lomb "Spectronic 20" colorimeter at 515 mu within 15 seconds after the addition of NaOH (1, 7).

Aliquots of 25 and 50 ul of the isopropanol solutions were spotted onto Whatman #1 paper and developed in N-butanol : acetic acid : water solvent (4 : 1 : 2 v/v) to determine ortho dihydroxyphenols present. Twenty ug samples of chlorogenic and caffeic acids were spotted as controls to aid identification based on Rf values.

Methods for detecting spindling-sprouted tubers.—Several chemical and mechanical tests were evaluated for separating spindling- and normal-sprouted tubers. Selection of tubers was accomplished after sprouting to provide known normal and abnormal samples.

Specific gravity determination.—Several investigators (5, 12) have reported spindling-sprouted tubers to have higher moisture content and thus lower dry matter than normal tubers. Specific gravity of individual tubers was determined by weighing them first in air then in water according to the procedure suggested by Edgar (3).

Spindling-sprouted and normal tubers of the White Rose and Russet Burbank varieties were measured as 5 separate lots collected in 1955 and 1956. In each case normal tubers came from the same lot which supplied tubers producing spindling sprouts.

Refractometer measurements of soluble solids.—Another consistent characteristic of spindling-sprouted tubers is an increase in reducing and total sugar content (5, 12, 19). Juice was extracted from a small portion of the stem end of tubers of both types and soluble solids content, calculated as sucrose, was measured in a Zeiss hand refractometer.

Three lots of tubers grown at Davis were sampled; Russet Burbank normal and spindling-sprouted tubers from general field plantings in 1957 and White Rose and Russet Burbank tubers from the 1958 aster yellows virus plot.

Ultraviolet fluorescence.—Tubers of both varieties were divided after germination into 1) spindling-sprouted, 2) normal-sprouted tubers from plants which also produced abnormal tubers, and 3) normal-sprouted tubers from healthy control plants. One-inch sections were removed from the stem end of each tuber and the exposed cross section examined immediately under an ultraviolet lamp.

An additional 107 White Rose and 718 Russet Burbank tubers from the 1958 Tulelake crop were examined prior to germination for ultraviolet fluorescence. These tubers were sprouted at room temperature after examination to correlate fluorescence patterns and spindling sprout in the event of abnormal sprout development.

Ferric chloride test for chlorogenic acid.—The periderm was removed from a small portion of the washed surface of spindling-sprouted and normal tubers from an aster yellows virus plot and a few drops of 2% ferric chloride solution applied. The color change from yellow to green

was recorded numerically by the rating of Schaal *et al.* (16) as follows: 0—no green color; 1-2—weak green color; 3-4—strong green color.

Anatomical studies of spindling-sprouted tubers.—Anatomical studies comparable to those in Europe have not been conducted on spindling-sprouted tubers in the United States. Therefore, sections of normal and abnormal tubers of the 2 varieties obtained from the aster yellows virus planting were prepared for microscopic examination by the paraffin infiltration method. Tissues from eye and non-eye areas of sprouted tubers and from sprouts of the 2 tuber types were fixed in Randolph's modified Navashin's fixative, dehydrated through a tertiary butanol-ethanol series (6), and imbedded in Fisher's tissuemat (MP 54-56° C). Paraffin sections 10-15 u thick were stained with hematoxylin-lacmoid and examined for gross anatomical differences and collose deposits in phloem tissues.

Results

Growth regulator content: The histograms in Fig. 1 represent composited growth-regulator data developed by the Avena coleoptile straight growth assay. Growth in length of test coleoptiles was calculated as percentage mean growth of 20 control coleoptiles. Areas in black indicate significance at the 5% level. Locations of substances detectable on extract chromatograms by ultraviolet examination and by perchloric acid-$FeCl_3$ color development are also indicated.

Chromatograms of extracts of normal and abnormal eye tissue of the White Rose variety (Fig. 1) contained equivalent areas of fluorescence and color development by colorimetric examination. A growth promoting substance comparable to indoleacetic acid (IAA)in movement on the chromatogram produced significant increased growth of coleoptiles exposed to extracts of both tuber types.

Chromatograms from extracts of Russet Burbank tubers (Fig. 1) exhibited a zone comparable to IAA when treated with perchloric acid-$FeCl_3$ solution and the same 2 zones of fluorescence under ultraviolet light as detected in White Rose tuber extracts. The IAA zone for only the spindling-sprouted extract produced highly significant promotion of coleoptile growth. A portion of an ultraviolet fluorescent zone (Rf .55-.65) compared rather closely with a highly significant inhibition of coleoptile growth in the normal extracts. No inhibition of coleoptile growth was produced in spindling-sprouted extracts.

Organic acid composition: Organic acids present in the 2 varieties appeared similar, but differences were evident between normal and spindling-sprouted tuber types (Fig. 2). Two spots were present on chromatograms of spindling-sprouted tuber extracts which did not appear on chromatograms of normal tuber extracts of either variety. One acid at Rf 0.15 was probably tartaric acid on the basis of Rf values. A second organic acid, the identity of which was not determined, appeared at Rf 0.075-0.10. Spots corresponding to Rf values of malic and citric acids were consistently present in quantities detectable by bromphenol blue indicator. Occasional differences in the presence or absence of *a* keto glutaric and succinic acids were noted on chromatograms depending upon growing areas furnishing the samples and different dates of analysis, but not due to tuber types.

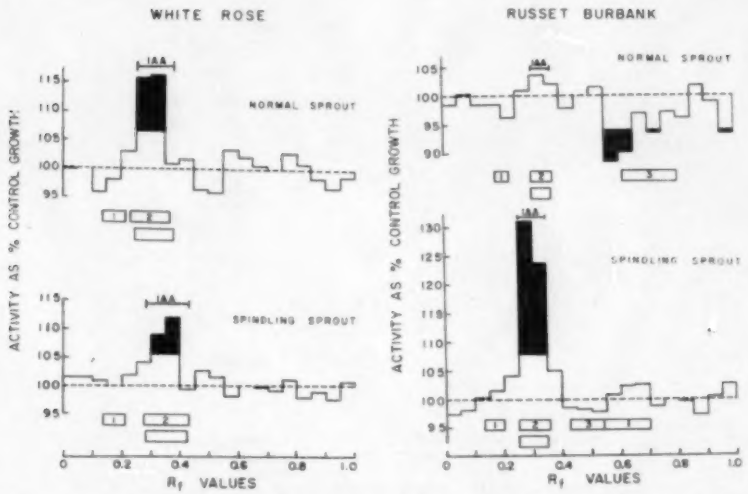

FIG. 1.—Histograms of biological activity of substances in White Rose and Russet Burbank normal and spindling-sprouted tuber eye extracts as determined by Avena coleoptile growth. Areas in black represent growth deviation significant at 5 per cent level. Numbered zones represent blue fluorescence under ultraviolet as 1) light, 2) dark and 3) very faint. Unnumbered zone represents pink color development in perchloric acid-ferric chloride spray test.

Chlorogenic acid: Chlorogenic and caffeic acids were detected on chromatograms of extracts from both normal and spindling-sprouted tubers. However, the predominant chlorogenic acid was assumed to be the principal polyphenol compound contributing to colorimetric readings.

Chlorogenic acid concentrations were high in sprout and periderm tissues and low in the flesh (Table 1). Data from 2 locations failed to reveal a characteristic or consistent pattern of chlorogenic acid in tubers predisposed to spindling sprout, normal tubers, or their respective sprouts. Differences that appear between varieties and between tuber types for the Tulelake samples of sprout and periderm eye tissue are exactly reversed in the Davis samples.

Evaluation of rapid methods for detecting spindling-sprouted tubers:

Specific gravity determinations: The mean specific gravity value for tubers producing spindling sprouts was lower than the mean value for normal tubers in each of 5 tuber lots tested. Data for numbers of tubers and mean specific gravity values are presented in Table 2.

Bar graphs were constructed by grouping values from individual tubers into specific gravity classes of 0.050 intervals, with the purpose of determining if differences in specific gravity would permit separation of individual tubers into spindling- and normally-sprouted. There was a definite trend for the spindling-sprouted tubers to fall within the lower

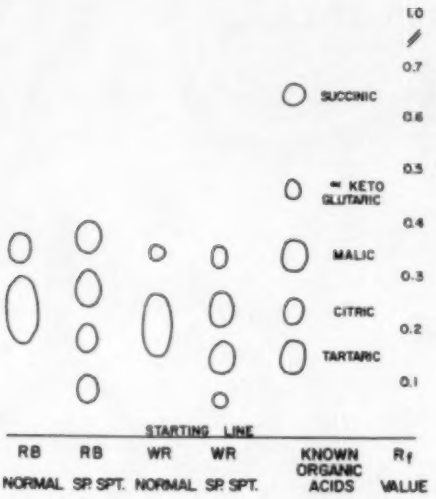

FIG. 2.—Schematic representation of organic acid in Russet Burbank (RB) and White Rose (WR) normal and spindling-sprouted (sp. spt.) tuber extracts. Location, identity and Rf value of known organic acids are presented.

TABLE 1.—*The average chlorogenic acid (CA) concentration of Russet Burbank and White Rose normal and spindling-sprouted tubers and sprouts from two growing areas.*

Variety	Tissue sampled	Tulelake[1]		Davis[2]	
		Normal Sprouted	Spindling Sprouted	Normal Sprouted	Spindling Sprouted
		mg CA/100 g fresh weight			
Russet Burbank	Sprouts	108	73	106	113
	Periderm, eye	88	64	77	91
	Periderm, noneye	45	43	78	103
	Cortex, eye	23	22	--	--
	Cortex, noneye	24	22	--	--
White Rose	Sprouts	115	351	188	95
	Periderm, eye	80	108	102	89
	Periderm, noneye	38	40	69	59
	Cortex, eye	37	33	--	--
	Cortex, noneye	19	21	--	--

[1]Tulelake tubers were obtained from storage in 1957.
[2]Davis tubers were obtained from aster yellows virus plot in 1958.

TABLE 2.—*Mean specific gravity values of five separate lots of White Rose or Russet Burbank spindling-sprouted and normal tubers from three locations.*

Variety	Location	Growing season	Tuber Type			
			Spindling-sprouted		Normal-sprouted	
			Number	Mean Sp. Gvt.	Number	Mean Sp. Gvt.
WR	Delta	1955	57	1.060	250	1.069
WR	Tulelake	1955	97	1.061	63	1.068
RB	Tulelake	1955	70	1.063	70	1.066
WR	Davis	1956	57	1.072	44	1.075
RB	Davis	1956	22	1.077	50	1.080

TABLE 3.—*Refractometer readings of soluble solids for three lots of normal and spindling-sprouted tubers.*

Variety	Year	Sprout type	Number of tubers measured	Mean soluble solids (% sucrose)	Standard deviation (s)	Range (% sucrose)
Russet Burbank	1957	Normal	56	6.1	.55	4.0- 7.4
		Spindling	30	8.4	.91	6.8-10.0
Russet Burbank	1958	Normal	50	6.6	.65	5.3- 8.0
		Spindling	29	9.4	.99	8.0-12.0
White Rose	1958	Normal	50	6.3	.63	5.0- 8.0
		Spindling	25	8.6	.89	6.6-10.0

specific gravity classes and the normal tubers to group into the higher values (Fig. 3).

Refractometer values for soluble solids: The increased sugar content in tubers predisposed to spindling sprout as determined by chemical methods is sufficiently high to be detected by refractometer readings for soluble solids. In each of 3 lots tested, the mean percentage soluble solids of spindling-sprouted tubers was consistently higher than that of normal tubers (Table 3).

Ultraviolet fluorescence: Fluorescent patterns of the tuber flesh, when examined by ultraviolet illumination, varied with variety and with sprouting type. Twenty-eight Russet Burbank spindling-sprouted tubers examined from the 1958 aster yellows virus plot exhibited only a faint blue fluorescence in the pith area with no fluorescence evident in the vascular cylinder or cortex. Normal tubers produced on both diseased (16 tubers) and healthy plants (21 tubers) reflected a yellowish-orange ring of color in the vascular cylinder and throughout the pith, and diffuse blue fluorescence in the cortex.

Twenty-one White Rose spindling-sprouted tubers revealed blue color throughout the cross section of the tuber, whereas normal tubers from diseased (18 tubers) and healthy plants (27 tubers) were reddish to

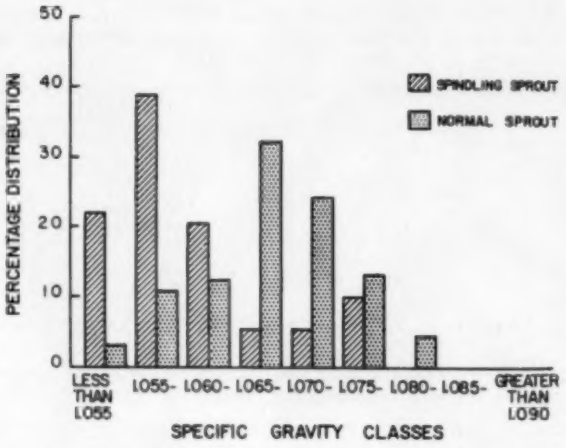

FIG. 3.—Distribution, by specific gravity classes, of White Rose spindling- and normal-sprouted tubers from the 1955 Delta crop.

pink throughout the pith and vascular cylinder, with white cortical fluorescence.

Non-sprouted Russet Burbank and White Rose tubers could be grouped into 3 fluorescent patterns; ring and cortical in which fluorescence was concentrated in the vascular cylinder or cortical areas, respectively, or diffuse, in which color was evident throughout the cross section of the tuber. Fluorescent patterns of the tuber prior to germination could not be correlated with spindling-sprout development, inasmuch as none of the tubers examined produced the abnormality.

Ferric chloride spot test: The variable content of chlorogenic acid in tuber periderm prevented separation of tubers into spindling- and normal-sprouted using the ferric chloride test. Both normal and spindling-sprouted tubers were distributed mainly within color classes 1-3, with occasional readings of 0 and 4 on individual tubers. This pattern of variability was consistent whether determinations were made on sprouted or non-sprouted tubers.

Anatomical features of spindling-sprouted tubers: Microscopic examination of the hematoxylin-lacmoid stained paraffin sections of tuber tissue revealed consistent deposits of callose at the ends of sieve tubes of inner phloem of spindling-sprouted tubers of both varieties (Fig. 4). No callose was observed in the undifferentiated vascular elements leading directly into developing eyes or sprouts. Sieve tubes of normal tuber phloem were generally free from callous deposits. An occasional thin flat layer of callose was observed along the sieve plate.. However, none of the sections of normal tuber tissue examined exhibited the heavy plugs of callose observed in spindling-sprouted tuber tissue.

Callose was not observed in the phloem of sprouts or developing shoots from either normal or abnormal tubers of either variety.

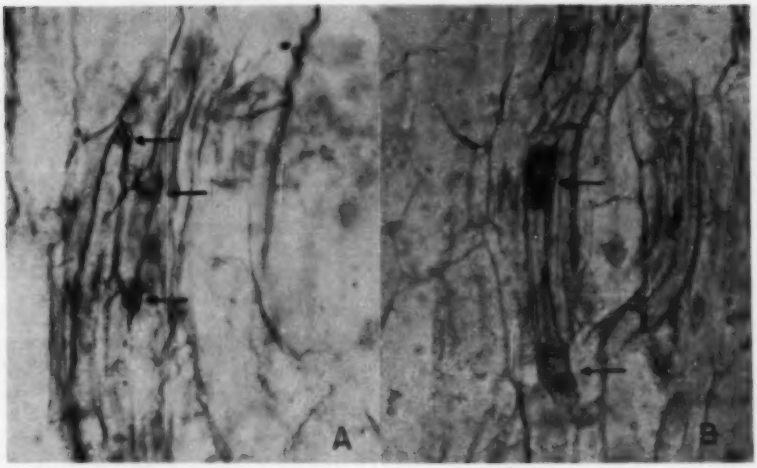

FIG. 4.—Callose deposits in phloem sieve tubes of White Rose (A) and Russet Burbank (B) spindling-sprouted tubers. Callose deposites indicated by arrows.

No gross differences in vascular development were evident in normal and spindling-sprouted eyes which could serve to differentiate abnormal and normal tubers. Starch grains also offered no basis of separation as they appeared to be similar in size, number, and location within the cells.

DISCUSSION

The literature available on spindling sprout of potato tubers has developed from two viewpoints, the study of potato diseases for which the tuber abnormality appears as one symptom, and from the study of abnormal tubers alone, with little or no data available on the condition of parent plants. No extensive study of the physiology of spindling-sprouted tubers produced by a definite disease or environmental condition has been conducted, therefore limiting comparisons with information developed in the present study.

One consistent characteristic of spindling-sprouted tubers evident in this study and corroborated in the available literature is damage to the phloem, either in the tuber or in the main plant. The presence of heavy callose in phloem cells of abnormal tubers, and the absence of comparable deposits in normal tubers appears to be a reliable criterion for differentiating normal tubers and tubers predisposed to spindling sprout. The action of aster yellows virus on phloem tissues of many plants causes destruction of these tissues and prevents translocation of elaborated foods from the tops to the roots and subterranean storage areas. Other diseases of potato associated with spindling sprout, such as bunch top, haywire, late-breaking, potato witches' broom and tomato big bud viruses cause phloem disorders, and most of these diseases appear as a necrosis of phloem elements of the tuber (10). Colletotrichum wilt fungus causes a girdling of the lower

stem which restricts food transport to the tuber, and even the toxin injected by the psyllid insect has been shown to cause phloem necrosis and incite callous deposits in sieve tubes of the tuber phloem (4). Spindling sprout, therefore, seems to be a symptom of phloem degeneration which may be caused by a number of unrelated diseases or environmental factors, and is not in itself a symptom arising from a single incitant.

The high level of IAA in Russet Burbank spindling-sprouted tuber extracts is useful in explaining the excessive growth of spindling sprouts. However, extracts of the White Rose variety failed to substantiate this differential in IAA concentration between normal and abnormal tubers. Rabin and Klein (13) observed an inhibition of IAA oxidase by chlorogenic and caffeic acids. However, concentrations in the tuber did not indicate that these components would affect IAA levels in the tuber. Concentrations of chlorogenic acid in aster yellows infected leaves, petioles and stems (Lippert, unpublished data) were higher than in respective tissues from healthy plants, which might indicate that IAA concentrations in tubers may be influenced by polyphenol concentration in the foliage and may not be dependent upon actual concentration in tubers.

The appearance of growth inhibitors in extracts of normal tubers of both varieties and their absence in extracts of spindling-sprouted tubers may have some bearing on the characteristic early sprouting of abnormal tubers.

Organic acid studies did not reveal any consistent differences in tricarboxylic acids which would be concerned with respiration. The two acids, one with Rf value equivalent to tartaric acid, present in spindling-sprouted and absent in normal tuber extracts may be associated with spindling-sprout development. Tartaric acid *per se* did not stimulate spindling-sprout production on non-sprouted tubers treated after harvest.

Spindling-sprouted tubers in California are similar to normal-sprouted tubers in both internal and external appearance, making it difficult to detect and eliminate abnormal tubers in advance of sprouting The chemical and mechanical tests conducted to detect spindling-sprouted tubers had two basic requirements; 1) the test must be rapid to permit examination of a large number of tubers and 2) it must be accomplished with a minimum loss of tuber tissue. These tests were conducted on tubers after sprouting to provide known spindling- and normal-sprouted samples. Therefore, evaluation of these results applied to non-sprouted tubers must await successful detection and separation of abnormal tubers from freshly harvested or non-sprouted lots.

Refractometer measurements for soluble solids was the most promising of the rapid tests. The distibution and range of spindling-sprouted and normal tubers were sufficiently distinct to minimize excessive overlap of the two types. Harvey *et al.* (5) report that sugar concentration of spindling-sprouted tubers is independent of storage temperature and should, therefore, be a reliable indication of the disorder over a range of temperature conditions.

Separation of individual tubers by specific gravity values could be effected by brine solutions to replace the laborious technique reported. Under critical control of the brine, the test should have valid application. In both refractometer and specific gravity separations, an initial sampling

of pre-sprouted tubers would be necessary to estimate the range of values and provide a separation point for normal and abnormal tubers.

Ultraviolet fluorescent patterns displayed by known spindling-sprouted tubers of White Rose and Russet Burbank varieties were distinct enough from normal tubers to achieve separation with a high degree of reliability. Non-sprouted tubers, which produced normal sprouts when germinated, exhibited variable fluorescent patterns, but did not produce patterns similar to those of tubers with spindling sprouts. The ultraviolet technique would offer rapid examination of a large number of tubers.

Summary

Concentration of a growth-promoting substance (IAA) was significantly higher in Russet Burbank spindling-sprouted tuber extracts than in extracts from normal tubers, whereas an inhibiting substance was present in significant amount only in normal tuber extracts. No differential in growth regulators was observed in tubers of the White Rose variety. Two organic acids, one similar in Rf value to tartaric acid, observed in chromatograms of extracts from spindling-sprouted tubers, were absent from chromatogramed extracts of normal tubers. Differences in chlorogenic acid were not consistent in the two tuber types.

Rapid tests for specific gravity, soluble solids and ultraviolet fluorescent patterns appeared reliable for detection and separation of known spindling- and normal-sprouted tubers. Abnormal tubers in general, measured low in specific gravity and high in soluble solids. The ferric chloride test for chlorogenic acid was not reliable for separating abnormal and normal tubers.

Callose deposits were observed in the internal phloem of lacmoid-stained sections of spindling-sprouted tubers by microscopic examination. Comparable callose deposits were not evident in normal-sprouted tuber tissue .

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DISINFECTANTS AND POTATO RING ROT CONTROL[1]

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Although bacterial ring rot of potato caused by *Corynebacterium sepedonicum* (Spieck. & Kotth.) Skapt. & Burk. was first found in North America some 20 years ago, it continues to be one of the most important potato diseases known today. At one time, it was thought that the placing of a zero tolerance for ring rot on seed potatoes was the answer to the control of this disease. Experience has shown, however, that this regulation has not proved to be a solution to the problem.

Undoubtedly the proper disinfection of potato storages and handling equipment is an important phase of ring rot control. This practice, however, is of little value if the new seed source is infected. It is often difficult to determine if infection resulted from contamination of clean seed during cutting or planting, or if the seed source itself was infected.

In the light of these observations, it would seem that there are three logical approaches to the problem of controlling bacterial ring rot infection, namely: [1] the breeding of immune varieties; [2] the use of a seed-treatment material that will kill the bacteria in the tuber or become systemic in the plant and thus prevent the spread of bacteria to the daughter tubers; [3] the proper disinfection of storages and potato handling equipment.

Many kinds of materials have been recommended for the disinfection of cutting knives, planters, storages, etc., in the control of bacterial ring rot. The initial recommendations by Racicot et al (8) called for the use of formalin, 1 pint to 25 gal. and copper sulphate, 1 lb. to 10 gal. Knorr (5) in 1947 stated "When tested against ring rot, formaldehyde was found by several investigators to afford not only no control, but actually to cause a spread of ring rot." Other materials that have been recommended are iodine (1), corrosive sublimate (3), boiling water (4), steam (10), moist heat (9), Semesan Bel (3), Lysol (8), quaternary ammonium compounds (5, 6), and antibiotics (7). Different researchers working with the same or similar compounds have reported entirely different results. A search of the literature, on the whole, serves only to confuse the reader who is attempting to find a suitable disinfectant for ring rot control.

In the past few years, there have been significant advances in the formulation of new and more specialized disinfectants, including antibiotics, and it seems reasonable to assume that some of these may be more suited for use in disinfection for ring rot control than some of those formerly recommended. This paper deals with a comparison of the effectiveness of a number of compounds, including some antibiotics, in killing the ring rot organism on a variety of materials, as well as within the potato tuber.

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Materials and Methods

The culture of *Corynebacterium sepedonicum* (Spieck. & Kotth.) Skapt. & Burk. used in these experiments was isolated in 1942. It was tested annually and found to have retained its pathogenicity. The solid medium used in the various experiments was of the following composition: dextrose proteose #3 agar, 40 g; yeast extract, 5 g; asparagine, 1 g; water, 1 liter; adjusted to ph 7.0. The liquid medium was described by Richardson (9) and had the following composition: casamino acids, 1 g; yeast extract, 1 g; dextrose, 1 g; calcium pantothenate, 0.1 g; water 1 liter; adjusted to pH 7.0.

Comparison of disinfectants by paper-disc assay method

Sixteen antibiotics and 11 other disinfectants were selected for testing in the laboratory. These materials were compared by dipping filter paper discs in solutions of each for 5 minutes and then placing the discs on an agar medium seeded with a standard suspension of the ring rot organism. The activity of the various materials was assessed by measuring the zone of inhibition surrounding the filter paper disc after an incubation period of 7 days at 70° F. Each test was replicated 5 times The active ingredients of the compounds listed as Trade Names are as follows: Agri-mycin, streptomycin sulphate, 15%, oxytetracycline hydrochloride, 1%; Agristrep, streptomycin sulphate, 15%; Cresanol, coal-tar formulation, phenol coef. 6; Purina, alkyl dimethyl 3, 4-dichlorobenzyl ammonium chloride, 4.5%, alkenyl dimethyl ethyl ammonium bromide 0.9%; Teramine, alkyl tolyl methyl trimethyl ammonium chloride, 10%; Semesan Bel, hydroxymercurinitrophenol, 12%, hydroxymercurichlorophenol, 3.2%; Hyamine 2389, alkyl tolyl methyl trimethyl ammonium chloride, 50%; R-2-L - alkyl dimethyl benzyl ammonium chloride, 10%; Lysol - orthohydroxydiphenyl and cresylic acid, phenol coefficient 5; San-O-Fec 25 - alkyl tolyl methyl trimethyl ammonium chlorides, ethylene diamine tetra-acetic tetra sodium salt, trisodium phosphate, sodium carbonate, 25.5%; Ocean 101 - alkyl tolyl methyl trimethyl ammonium chloride, 10%.

The results (Table 1) indicate a wide variation in the activities of various products against the ring rot organism. Agri-mycin, Agristrep, Erythromycin, Terramycin, Streptomycin, Penicillin G, and Phytomycin were the most active of the antibiotics tested. The mercuric compounds Semesan Bel and mercuric chloride were the most active of the other disinfectants, with the quaternary ammonium compounds such as Teramine, Hyamine 2389, Purina, R-2-L, San-O-Fec 25, and Ocean 101 being of equal potency (Fig. 1). It is interesting to note that both copper sulphate and formalin, when tested at the concentrations recommended, were inferior to both the quaternary ammonium and mercuric compounds. Cresanol, formalin, and copper sulphate appeared to arrest the growth of the ring rot organism for a time, but this effect was only temporary, for the zones eventually became overgrown with the bacteria.

Treatment of metal, wood, and jute with disinfectants

A variety of materials including metal, wood, jute fibre, and cotton must be treated for the control of ring rot. In the laboratory, experiments were designed so that each disinfectant would be used on wood, metal, and jute fibres, the respective test materials being toothpicks, razor

TABLE 1.—*Inhibition of the potato ring rot organism by various antibiotics and other disinfectants (paper-disc assay method).*

Disinfectant	Concentration Active Ingredient ppm	Manufacturer	Zone of Inhibition* mm
Agri-mycin	100	Pfizer	69
Agristrep	100	Merck	62
Chloromycetin	100		60
Erythromycin	100	Lilly	68
Streptothricin	100		41
Terramycin	100		71
Griseoviridin	100		43
Neomycin	100		35
Penicillin G	100	Lilly	70
Streptomycin	100		68
Viridogrisin	100		41
Phytomycin	100		68
Cresonol	25000		45**
Purina	300		57
Formalin	5000		39**
Teramine	300	West Disinfecting Co.	61
Semesan Bel	1 lb/4 gal.	Du Pont	90
Mercuric chloride	1000		90
Hyamine 2389	300	Rohm and Haas	62
R-2-L	300	G. H. Wood & Co.	61
Copper sulphate	1 lb/10 gal.		17**
Lysol	40000		48
San-O-Fec 25	300	Whitmoyer Lab.	60
Ocean 101	300	Ocean Chemicals	61

*Five replicates.
**Zone cloudy.

blades, and 3-in. jute strands. The test materials were sterilized for one hour at 20 pounds pressure in an autoclave and then placed in a heavy suspension of ring rot bacteria for 48 hours. The materials were then removed and dried for 3 days in a desiccator over calcium chloride. Following drying the materials were soaked for 5 minutes in one of the 24 disinfectants listed in Table 1. The efficiency of the treatment was determined by plating the treated materials on solid medium and by incubating them in tubes containing 15 ml. of liquid medium on a shaker. Two toothpicks, two jute strands, and one razor blade were used in each treatment, and the treatments were replicated 5 times. Results were recorded after a 14-day incubation period. Where growth occurred, the organism was identified by microscopic examination of Gram-stained smears.

Complete disinfestation was obtained on wood, metal, and jute with the following disinfectants: Agri-mycin, Agristrep, Erythromycin, Terramycin, Penicillin G, streptomycin sulphate, Phytomycin, Cresanol, Purina, Teramine, Semesan Bel, mercuric chloride, Hyamine 2389, R-2-L, Lysol, San-O-Fec 25, and Ocean 101 (Fig. 2). Growth occurred on the jute fibres and wood materials treated with streptothricin, griseoviridin, neo-

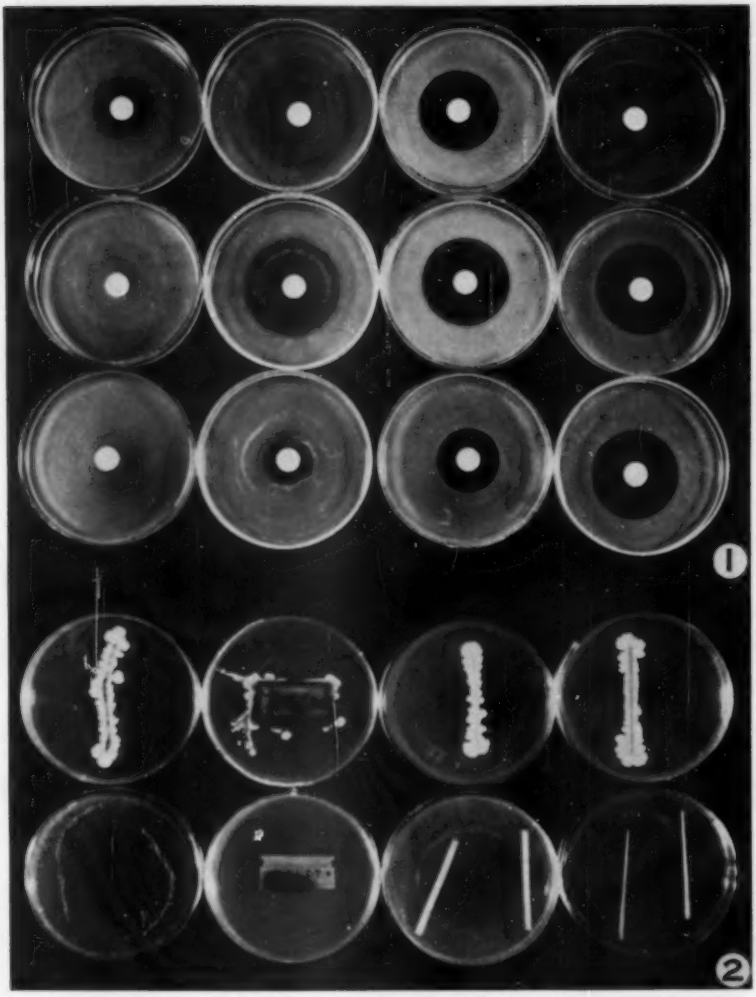

Fig. 1.—The activity of disinfectants against *Corynebacterium sepedonicum*. Left to right: Top row: formalin, 1:100; Cresanol, 1:40; R-2-L, 300 ppm; mercuric chloride, 1:1000; Middle row: formalin, 1:200; Lysol, 4%; San-O-Fec 25, 300 ppm; Teramine, 300 ppm; Bottom row: control; copper sulphate, 1 lb/10 gal.; Purina, 300 ppm; Hyamine 2389, 300 ppm.

Fig. 2.—Disinfection of contaminated wood, metal and jute with Hyamine 2389, 300 ppm. Top row: untreated controls; Bottom row: materials treated for five minutes with Hyamine 2389.

mycin, viridogrisn, formalin, and copper sulphate. Viable ring rot bacteria were observed on all materials not treated with a disinfectant.

Field trials for cutting knife disinfectant

In 1957 and 1958, the efficiency of the 24 disinfectants in eliminating ring rot bacteria from the cutting knife was determined. The knife was contaminated by cutting through an infected tuber, then dipped momentarily in a jar of the disinfectant and used immediately to cut 4 sets from a healthy tuber. This was repeated until 16 sets had been cut. The sets were then planted in the field and the tubers examined microscopically when harvested.

Only mercuric chloride and Semesan Bel gave complete control, although many of the other materials gave partial control.

The specificity of disinfectants

Although formalin has been used widely as a disinfectant in hospitals, etc., it did not appear to be as active against the bacterial ring rot organism as did many of the other materials tested. To determine if some of the disinfectants being tested showed a degree of specificity for a particular organism, Hyamine 2389, Teramine, Lysol, copper sulphate, and formalin were tested against *Bacillus subtilis*, Cohn Emend. Prazmowski, *Erwinia carotovora* (L. R. Jones) Holland, and *Corynebacterium sepedonicum*. Hyamine 2389 and Teramine were used at 300 ppm, Lysol at 5%, copper sulphate at 1 lb/10 gal., and formalin at 1 pt/25 gal. The paper-disc assay method previously described was used, - replicated 5 times.

Hyamine 2389 and Teramine gave zones of 62 mm, 56 mm, and 31 mm in tests with *C. sepedonicum*, *B. subtilis*, and *E. carotovora*, respectively. Cloudy zones of approximately 17 mm were observed when copper sulphate was tested against all 3 organisms. Lysol gave zones of 47, 36, and 45 mm, and formalin gave zones of 36, 39, and 61 mm against *C. sepedonicum*, *B. subtilis* and *E. carotovora*, respectively. Formalin was consistently more active against the soft rot organism, *E. carotovora*, than was any other disinfectant, whereas Lysol and the quaternary ammonium compounds gave consistently better results against the other 2 organisms.

Disinfection of potato sacks contaminated with Corynebacterium sepedonicum

Five disinfectants, Hyamine 2389, formalin, Ocean 101, Terramycin, and Agristrep were selected for use in this experiment. Hyamine 2389 and Ocean 101 were used at 300 ppm, Terramycin and Agristrep at 100 ppm, and formalin at 1 pint to 25 gal. of water.

The bags were treated in 5 lots of 50 bags each. Each 10th bag of each lot had previously been contaminated with *C. sepedonicum* by shaking 50 infected cut sets in them. Each of the 5 lots was soaked for one hour in 40 gal. of the disinfectant; each bag was then run through a washing machine wringer and allowed to dry in bright sunlight at 75° - 80° F. The 5 contaminated bags were selected from each lot. Fifty seed pieces cut from healthy Green Mountain tubers were placed in each of the 5 contaminated bags from each lot, thoroughly shaken, and then planted in the field. After the tubers were harvested they were examined for ring rot. There were 2 sets of controls: [1] bags were

TABLE 2.—*A comparison of the efficiency of five disinfectants, including two antibiotics, in killing Corynebacterium sepedonicum on jute bags.*

Treatment	Concentration (ppm)	Percentage of tubers with ring rot 1955	1956	1957	Av.
Hyamine 2389	300	0	0	0	0
Ocean 101	300	0	0	0	0
Formalin	5000	2.7	0	1.4	1.4
Terramycin	100	1.1	1.2	1.4	1.2
Agristrep	100	1.2	0	1.1	0.8
Tap water	—	2.1	1.2	1.3	1.8
No soak	—	13.3	8.1	12.6	11.3

soaked in tap water for one hour and then dried; [2] the bags were not soaked.

Hyamine 2389 and Ocean 101 were superior to the other materials in the treatment of contaminated bags. It is also evident that soaking contaminated bags for one hour, even in tap water, reduces their potential to contaminate cut sets placed in them. In the three years of this experiment, 11.3% of the tubers produced from cut sets placed in contaminated bags became infected. This indicates that contaminated bags are an important means of spreading bacterial ring rot.

Volume of disinfectant required for treating potato bags

Forty gallons of Hyamine 2389 at a concentration of 300 ppm were mixed in a large drum. Used potato bags were divided into 50-bag bundles in which each 10th bag was contaminated with *C. sepedonicum*. Eight of these 50-bag lots were treated consecutively in the disinfectant without the addition of fresh disinfectant. As each lot of bags was removed, the bags were run through a washing machine wringer and the extracted disinfectant returned to the drum. After the bags had been dried on a clothesline, those that had been contaminated were removed from each lot and the presence or absence of viable ring rot bacteria was determined by placing 50 freshly cut Green Mountain sets in each bag and shaking vigorously. The sets were then planted, and the presence of disease determined by microscopic examination of the tubers produced. A control series was run with tap water in place of a disinfectant.

Trace amounts of bacterial ring rot were found in tubers grown from sets shaken in the sixth lot of bags treated in disinfectant. The percentage of bacterial ring rot found in the seventh and eighth lot was of the same magnitude as that in the control. Under the conditions of this experiment, 250 used bags can be safely treated in 40 gal. of disinfectant. This number will, of course, vary with the cleanliness of the bags, and with the degree of hardness of the water used in diluting the disinfectant.

Soaking infected seed-pieces in disinfectant solutions

Tubers of Foundation Green Mountain potatoes were inoculated with bacterial ring rot by placing a drop of bacterial suspension on each eye and puncturing the epidermis around the eye several times with a needle. After storage at 45° F. for 5 weeks, the tubers were each cut into 4

sets. Six liters of each of the disinfectant solutions were prepared at two concentrations, usually 500 and 1000 ppm. Each preparation was then divided into two 3-liter lots, and 25 freshly cut sets were placed in each and allowed to soak for periods of 6 or 16 hours. On removal, the sets were dried at 70° F. and then planted in the field. The efficiency of the treatments was determined by examining the harvested tubers microscopically.

The coal-tar products such as Cresanol were extremely phytotoxic, whereas most antibiotics had little effect on the total yield of tubers (Table 3). It was evident that the quaternary ammonium compounds in general were of limited value as seed-piece soaks. Many were quite phytotoxic, and the control of ring rot was not satisfactory.

The material which gave the best control of bacterial ring rot was Terramycin (oxytetracycline hydrochloride), but it was also quite phytotoxic at the concentrations used in these tests. It is interesting to note the difference in effectiveness of Agristrep and Agri-mycin. Both materials are primarily streptomycin sulphate compounds, but Agrimycin contains approximately 1% oxytetracycline hydrochloride. It is apparently the presence of this material which makes Agri-mycin effective as a seed-piece soak. In considering both phytotoxicity and disinfectant properties, Agri-mycin was the most suitable seed-piece soak. On the basis of these results, it appeared desirable to compare Terramycin and Agri-mycin as seed-piece treatments at a number of concentrations and durations of soaking.

A comparison of Agri-mycin and Terramycin as seed-piece disinfectants

Green Mountain tubers were inoculated and stored as in the previous test. Ten freshly cut seed-pieces were placed in one-liter quantities of each of the disinfectants, Agri-mycin and Terramycin, prepared at concentrations of 100, 200, and 300 ppm. The seed-pieces were soaked for periods of 6, 16, and 24 hours. Inoculated seed-pieces soaked in water served as controls. The efficiency of the treatments was determined by the microscopic examination of tubers at harvest for presence of bacterial ring rot.

The control of bacterial ring rot by soaking seed-pieces in Terramycin was very inconsistent (Table 4). Although the percentage infection in treated samples was considerably less than that in the controls, there was definite evidence of phytotoxicity. The toxicity was not always greatest at the highest concentration of antibiotics or with the longest period of treatment. In this test, Agri-mycin was as effective in the control of ring rot in potato tubers as was Terramycin.

Effect of state of dormancy of the tuber on phytotoxicity in treatments with Terramycin

A series of tests was designed to determine if the seed-piece is as subject to the toxic reaction of antibiotics during dormancy as in subsequent stages up to the formation of sprouts. One hundred dormant tubers were cut and soaked in 300 ppm Terramycin for 24 hours. A similar treatment was given cut tubers which were just breaking dormancy and to a third lot of tubers which had sprouts approximately ¼ in. in length. The controls consisted of 3 lots of sets soaked in tap water for

TABLE 3.—*Incidence of bacterial ring rot in a potato crop grown from inoculated seed pieces soaked in disinfectants.*

Disinfectant	Concentration	Duration of treatment (hr.)	Tubers harvested	
			No.*	% B.R.R.†
Semesan Bel	1 lb/10 gal.	6	105	9.5
" "	1 lb/10 gal.	16	8	12.5
$HgCl_2$	1:500	6	172	7.6
"	1:1000	6	178	3.4
"	1:500	16	60	0
"	1:1000	16	101	5.0
Teramine	1000 ppm	6	80	21.3
"	500 ppm	6	110	4.5
"	1000 ppm	16	20	0
"	500 ppm	16	139	6.5
Ocean 101	1000 ppm	6	104	5.8
"	500 ppm	6	154	20.8
"	1000 ppm	16	76	9.2
"	500 ppm	16	130	10.8
Purina	1000 ppm	6	139	19.4
"	500 ppm	6	154	27.3
"	1000 ppm	16	111	2.7
"	500 ppm	16	178	6.7
Hyamine 2389	1000 ppm	6	83	4.8
"	500 ppm	6	133	1.5
"	500 ppm	16	50	2
San-O-Fec 25	1000 ppm	6	38	31.6
"	500 ppm	6	83	7.2
"	500 ppm	16	53	20.8
Terramycin	1000 ppm	6	12	0
"	500 ppm	6	83	0
"	1000 ppm	16	96	0
"	500 ppm	16	31	0
Agristrep	1000 ppm	6	195	0.5
"	500 ppm	6	179	5.0
"	1000 ppm	16	40	5.0
"	500 ppm	16	65	0.1
Agrimycin	1000 ppm	6	148	0
"	500 ppm	6	175	1.1
"	1000 ppm	16	62	0
"	500 ppm	16	91	0
Water Soak		6	170	68.8
		16	118	82.2

*No tubers were harvested from sets treated with the following: Semesan Bel — 1 lb/5 gal., 6 and 16 hrs.; Cresanol — 1:40 and 1:100, 6 and 16 hrs.; Hyamine 2389 — 1000 ppm, 16 hrs.; San-O-Fec 25 — 1000 ppm, 16 hrs

†4 replicates.

24 hours and a lot freshly cut, but not soaked. The treatments were replicated four times. Following treatment, the sets were allowed to dry and were then planted in the field. During the season, records were taken on emergence, vigor, and yield. The degree of phytotoxicity was based on time of emergence, on abnormalities, and on general vigor of the plants.

Tubers which were sprouted when soaked in either antibiotics or water for 24 hours were slow to germinate when planted and gave yields 75% lower than those from untreated tubers (Table 5). The toxicity of

TABLE 4.—*Agri-mycin vs. Terramycin as seed-piece soaks in the control of bacterial ring rot.*

Disinfectant	Concentration ppm	Duration of treatment (hrs)	Tubers harvested*	
			No.	% B.R.R.
Terramycin	100	6	0	
		16	80	5
		24	12	0
	200	6	76	7.9
		16	56	7.1
		24	50	4.0
	300	6	38	5.3
		16	54	0
		24	26	0
Agri-mycin	100	6	42	28.6
		16	22	18.2
		24	46	8.7
	200	6	36	27.8
		16	18	0
		24	24	0
	300	6	30	13.3
		16	46	21.7
		24	14	0.
Water control		6	32	81.25
		16	16	75.00
		24	0	
No treatment			113	0

*Four replicates.

TABLE 5.—*Relative susceptibility of dormant and sprouted tubers to the phytotoxic action of Terramycin.*

State of Tuber	Treatment	Duration (hr.)	Phyto-toxicity*	Yield (lb.)†
Dormant	Terramycin 300 ppm	24	slight	312
Semi-dormant	Terramycin 300 ppm	24	moderate	233
Sprouted (¼")	Terramycin 300 ppm	24	severe	143
Dormant	tap water	24	slight	256
Semi-dormant	tap water	24	moderate	196
Sprouted (¼")	tap water	24	severe	112
Dormant	none	0	none	365
Semi-dormant	none	0	none	382
Sprouted (¼")	none	0	none	408

*As indicated by time of emergence, abnormalities, and plant vigor.
†Four replicates, each consisting of 100 seed-pieces.

the treatments was considerably less when dormant or semi-dormant tubers were treated. The severe toxicity encountered in some of the previous experiments and the lack of toxicity in others may well have been due to the state of the tubers at the time of treatment.

Effect of stage of dormancy of the tuber on the efficiency of antibiotic treatment of seed-pieces in ring rot control

Since the stage of dormancy of the tuber at the time of treatment influenced the phytotoxicity, it seemed possible that it might also influence the efficiency of the treatment.

Dormant, semi-dormant, and sprouted tubers which had been inoculated with *C. sepedonicum* one month previously were cut and treated for 6, 16, and 24 hours with a 300 ppm solution of Terramycin. Fifty tubers were used in each test, and the tubers were cut into sets just prior to treatment. Following treatment the tubers were planted in the field, and notes were taken on phytotoxicity, yield, and percentage bacterial ring rot in the crop. The percentage of bacterial ring rot was determined by microscopic examination of smears from the tubers.

These results indicated that Terramycin again reduced the amount of infection considerably (Table 6). The treatment of semi-dormant tubers with 300 ppm Terramycin for a period of 16 hours produced the best control of bacterial ring rot with the least phytotoxicity. Although there was a phytotoxic effect from Terramycin, the marketable yield from treated tubers exceeded that from untreated but infected tubers.

TABLE 6.—*Efficiency of antibiotic treatments as seed-piece soaks for tubers differing in degrees of dormancy.*

Tuber	Treatment†	Duration (hr.)	Yield (lb.)*	Tubers with B.R.R. %
Dormant	Terramycin (300 ppm)	6	183	3.6
	Terramycin (300 ppm)	16	141	3.1
	Terramycin (300 ppm)	24	86	2.2
Semi-dormant	Terramycin (300 ppm)	6	165	1.3
	Terramycin (300 ppm)	16	134	0
	Terramycin (300 ppm)	24	81	0
Sprouted	Terramycin (300 ppm)	6	146	0.8
	Terramycin (300 ppm)	16	86	1.4
	Terramycin (300 ppm)	24	53	0
Dormant	none		131	86.5
Semi-dormant	none		126	92.1
Sprouted	none		135	73.8

†Average of 4 replicates.
*Tubers inoculated with *C. sepedonicum* one month before treatment and stored at 36 to 40° F.

DISCUSSION

Because of the variety of materials which must be treated in attempting to control the spread of potato ring rot, it is difficult to recommend

a single disinfectant which will act efficiently on all of them. The quaternary ammonium compounds of the general formulation alkyl tolyl methyl trimethyl ammonium chloride were very efficient in the disinfestation of jute, wood, and metal surfaces, when instantaneous killing action is not required. For the potato cutting knife, where the activity must be instantaneous, none of the products tested was as efficient as mercuric chloride (1:500) or Semesan Bel (1 lb./4 gal.). Although these two mercury compounds are undesirable from the standpoint of toxicity to humans and their corrosive action on metals, they appear to have the instantaneous killing qualities required in certain disinfestation operations.

The quaternary ammonium compounds are effective disinfectants for a number of reasons. They are apparently able to kill the organism in a relatively short time, they possess wetting properties which allow the active ingredient to come in contact with the organism more readily, and their activity appears to be influenced less by the presence of organic matter than is the case with the antibiotics. The quaternary ammonium compounds are also odorless and relatively nontoxic to humans and animals.

There has been some question as to the role played by contaminated potato bags in the spread of bacterial ring rot. It is quite evident from the results reported in this paper that a high percentage of ring rot may appear in the succeeding crops if cut seed sets of a susceptible potato variety are placed in contaminated bags. Although barrels and crates were not tested in these experiments, it seems reasonable to assume that they too could serve as an efficient means of contaminating seed stock. It is, therefore, imperative that all potato handling equipment, and particularly that used in handling cut sets, should be thoroughly washed and disinfected.

Contaminated potato bags washed in tap water were found to transmit ring rot to fewer cut sets than did unsoaked bags. In the case of most bacteria, such a treatment would be expected to spread the bacteria more evenly through the jute strands and enhance the chances of contaminating sets. In the case of bacterial ring rot, although no direct experimental data are available, it is apparent that a high inoculum potential is necessary to incite infection. Soaking the bags in water would break up clumps of bacteria and, in this way, reduce the number of bacteria a seed piece could contact at any one time.

When treatments for used-bag disinfection are recommended, growers often ask how many bags can be safely disinfected in a given quantity of disinfectant. The results obtained in these investigations indicate that approximately 250 bags can be disinfected in 40 gal. of Hyamine 2389 (300 ppm). These bags had not been subjected to any special cleaning procedures and could be considered representative of the majority of potato bags which would be disinfected.

There appears to be a definite variation in toxicity of different disinfectants to different organisms. In these tests, formalin (1 pt./25 gal.) was less active against *C. sepedonicum* than were the quaternary ammonium compounds. However, formalin was superior to the quaternary ammonium compounds against *E. carotovora*. These results point out the necessity of testing different formulations of disinfectants against specific organisms, rather than recommending them on the basis of their activity

against some unrelated organism. If formalin is to be used as a disinfectant for ring rot control, it is suggested that a mixture of one pint to 10 gal. of water be used.

Because of the zero tolerance for bacterial ring rot in seed potatoes, any material for use in controlling ring rot in the seed-pieces should consistently give 100% control. In the case of table stock production, where complete control of ring rot is not a necessity, materials which give a high percentage of control and which are relatively non-toxic could be used. Those materials which were tested and which gave relatively good control of ring rot in the seed-pieces were quite phytotoxic. To date, the results of tests with antibiotics have been too variable to serve as a basis for any recommendations. These tests have, however, indicated that the process of treating seed-pieces with antibiotics or other materials and thus eliminating ring rot from the seed may be feasible. It may be possible, by soaking cut sets under vacuum, to shorten the soaking period, thus lessening the phytotoxicity and increasing the penetration of the disinfectant.

Antibiotics appear to be absorbed very slowly by the cut set. Absorption through the uninjured epidermis could not be demonstrated (7), and this would mean that in a normal 1.5-oz. set the disinfectant would have to travel a distance of from 1 to 2 in. along the vascular ring to come in contact with the bacteria.

Tuber infection in these experiments was determined by making smears and Gram stains of sections of the vascular ring at the stem-end. Although this is perhaps the best direct method of determining infection now available, it is quite possible that infections in which only a few bacteria are present could be missed. The alternative would be to examine the treated seed-lot through several generations. This would be a time-consuming operation, but would probably give a more precise estimate of the amount of infection.

Summary

1. Mercuric chloride (1:500) and Semesan Bel (1 lb./4 gal.) were superior to the other materials tested as cutting-knife disinfectants.
2. The quaternary ammonium compounds of the general formulation alkyl tolyl methyl trimethyl ammonium chloride were very efficient in the disinfestation of jute, wood, and metal surfaces when instantaneous killing action was not required.
3. When cut sets of a susceptible potato variety were placed in a contaminated potato bag, a high percentage of ring rot appeared in the succeeding crop.
4. Contaminated potato bags soaked in tap water transmitted bacterial ring rot to fewer cut sets than did unsoaked bags.
5. Under the conditions of these experiments, approximately 250 bags could be safely treated in 40 gal. Hyamine 2389 (300 ppm).
6. Although some of the materials which were treated as seed-piece disinfectants considerably reduced the amount of ring rot in the succeeding crop, they were quite phytotoxic and cannot yet be recommended for commercial use.

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EFFECT OF FERTILITY LEVEL ON THE INCIDENCE OF HOLLOW HEART[1]

ARVO KALLIO[2]

The distribution of hollow heart is general throughout the potato growing areas of the United States, including Alaska. It is a physiological disease of serious economic importance. This is especially true when present in an appreciable amount, since it is difficult to detect without cutting the tubers.

Hollow heart in Alaska has been most prevalent in commercial fields where susceptible varieties have been grown under high levels of nitrogen in relation to potash. Under these conditions the incipient form of the disease (8) has been detected early in the season, and together with potassium symptoms as exhibited by leaf mottling, scorch and rolling of the leaves.

The objectives of these studies were: 1) To determine if the incidence of hollow heart can be influenced in a susceptible variety by varying the levels of nitrogen (N), phosphate (P) and potash (K); 2) To determine the role and possible association of potassium in the development of hollow heart. Our present knowledge regarding the cause and nature of hollow heart is very limited and incomplete. Krantz (6) reviewed the literature on hollow heart and summarized present knowledge regarding the cause and nature of the disease. Levitt (8) studied its histological sequence. He found that the first sign is a group of several dead brown cells in the pith, surrounded by a zone of cells known as the wound pericambium. As the disease progresses a more or less irregular cavity forms in the center of the tuber. Decay is not associated with the cavity except when rotting fungi or bacteria enter from the outside.

According to Krantz (6) hollow heart in commercial fields has been associated with conditions favoring heavy vine growth during periods of rapid tuber enlargement. The most common condition observed has been an increased moisture supply after a period of more or less deficiency. Hollow heart has been found to be most prevalent in large tubers (3, 6, 7, 8, 9, 10, 13, 14). However, this disease is not confined to large tubers as it has been found in small tubers ranging in size as small as 1.8 grams (8).

Moore (10) noted an increase in hollow heart under wide spacing, on irrigated plots and on plots receiving potash and potash plus nitrogen. Application of phosphorus alone, and in combination with potash and nitrogen, reduced its incidence. He obtained the highest yields and lowest amount of hollow heart in plots receiving a complete fertilizer.

Werner (13, 14) found hollow heart to be very closely associated with growth cracks and oversized tubers. He obtained a reduction in the incidence of hollow heart by increasing the number of plants per acre. He did this by planting large seed pieces or whole tubers and treating cut seed with thiourea.

Moore (10), studying the development of hollow heart, observed

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that the incidence of the disease increased as the season progressed. He attributed this increase to an abnormal amount of rain that fell late in the growing season.

Krantz and Lana (7) observed that removal of 60 to 80% of the foliage 60 days after planting markedly increased the incidence of the disease. They found that foliage injury in itself is not the immediate cause of hollow heart as its increase seems to occur only when the injury is rapidly replaced by new growth. They suggested that the active renewal of vegetative growth following defoliation may have led to a temporary nutritional deficiency which initiated the development of the disease.

It appears that conditions favoring rapid vine growth during the rapid tuber enlargement phase tends to increase the incidence of hollow heart. Under these conditions, the physiological balance of the plant is altered and tops are produced at the expense of the tubers. It is possible under these conditions that important nutrients may be temporarily insufficient which would possibly result in the death of cells within the tuber caused by starvation, followed by subsequent development of hollow heart.

Materials and Methods

Exploratory studies to determine the incidence of hollow heart in a susceptible variety by varying the levels of Nitrogen (N), Phosphorus (P) and Potash (K) were conducted during the summers of 1958 and 1959 at College, Alaska (64° 50′ N. latitude). Plots were located on soil classified as Tanana, very fine sandy loam (5). It is typical of the soils in the area and is well suited for potato production. A 3 by 3 factorial field design with a single replication was employed. Fertilizer treatments were as follows: N refers to Nitrogen, P_2O_5 to Phosphorus, and K_2O to Potash.

	1958			1959		
	Pounds per acre of each element			Pounds per acre of each element		
Treatment	N	P_2O_5	K_2O	N	P_2O_5	K_2O
1	0	0	0	60	210	120
2	60	210	120	120	420	240
3	120	420	240	180	630	360

Nitrogen was supplied in the form of 33.5 % ammonium nitrate, phosphate in the form of 45% superphosphate, and potash in the form of 51% potassium sulfate.

Deep furrows were opened on May 22, 1958, and May 29, 1959, and fertilizers were applied uniformly by hand in the bottom of the furrows. Approximately two inches of soil were raked over the fertilizer, after which potato seed pieces of the Alaska 114 (2) variety were planted and covered. Each fertilizer plot consisted of five 10-foot rows, 38 inches apart, containing 14 seed pieces spaced approximately 8 inches apart.

To avoid fertilizer effects from adjacent plots only the center three rows were harvested, and this was done by hand on August 20 in 1958 and on September 8 in 1959. In both years tubers from each plot were graded by machine into three size groups, namely: Group one, 2 inch minimum; group two, 1½ to 1⅞ inches; group three, less than 1½

inches. Incidence of hollow heart was determined by cutting all tubers of each size. In this experiment a tuber was considered to have hollow heart only when the incipient form, as described by Levitt (8), was found. Specific gravity was determined by the hydrometer method (11).

Data obtained during the two-years' study were analyzed statistically using analysis of variance. Significance of differences between means was determined by the use of the Student Newman-Keuls (SNK) test as outlined by Federer (4).

Results

Potash deficiency symptoms such as leaf mottling, rolling and scorch were not visible in plots where high rates of potash were applied. In 1959 abnormal foliage symptoms were especially severe in plots where 120 pounds of potash per acre were applied, and in 1958 in plots where no potash was applied.

Plants in plots receiving high applications of nitrogen and potassium seemed more frost tolerant, being injured less by the frost of August 4, 1959, than were plants in plots receiving less nitrogen and potassium. None of the phosphorus applications appeared to alter the tolerance of the potato tops to low temperatures. Tuber number in 1959 was considerably greater than in 1958. This increase in the number of tubers in 1959 did not cause an increase in total yields. On the contrary, tuber size was reduced, causing an increase in weight of group 2 and group 3 tubers. Tuber number and weight of group 1 tubers was approximately 40% greater in 1958 than in 1959.

Two levels of NKP used in 1958 did not significantly influence the incidence of hollow heart in tubers of Alaska 114. However, plots receiving the highest nitrate applications (120 pounds per acre in 1958 to 180 pounds in 1959) and those receiving the lowest potassium applications in both years gave the highest incidence of hollow heart, 14 per cent in 1958 and 98 per cent in 1959, respectively.

All main effects of NPK significantly influenced tuber yield. NK significantly influenced the incidence of hollow heart, but only N significantly altered the specific gravity of the tubers.

Table 1.—*Total weight in pounds per plot, specific gravity, and per cent incidence of hollow heart of group one tubers of Alaska 114 grown under three levels of NPK in 1959.*

Nutrients applied separately in pounds per acre			Tuber yield pounds per plot			Means of indicated variables[1]					
						Hollow heart %			Specific Gravity		
N	P_2O_5	K_2O	N	P	K	N	P	K	N	P	K
60	210	120	14b	17a	11b	50b	65a	77a	1.0862a	1.0805a	1.0814a
120	420	240	19a	13b	17a	66a	63a	63a	1.0818a	1.0812a	1.0867a
180	630	360	16ab	18a	20a	73a	66a	42b	1.0761b	1.0823a	1.0820a

[1]Any two means within a particular treatment, not having a common letter, are significantly different at the 1% level.

Means of total tuber yield, specific gravity and per cent incidence of hollow heart of group one tubers of Alaska 114 under various treatments are given in Table I.

As shown in Table 1, increasing the nitrogen application from 60 pounds to 120 pounds per acre significantly increased tuber yield. Further increase in nitrogen to 180 pounds per acre tended to reduce yields. Phosphorus applications used in this experiment had very little effect on tuber yield, except that 420 pounds per acre tended to reduce yield. In 1958, the 420 pound rate tended to increase yields. Increasing potassium applications tended to increase tuber yield. The application of 240 pounds per acre increased yield more than did the application of 360 pounds per acre.

As seen in Table 1, increasing the nitrogen application from 60 pounds to 180 pounds per acre increased the incidence of hollow heart from 50% to 73%, respectively, or an increase of 46%. In contrast, increasing the potassium application from 120 pounds to 360 pounds per acre reduced the incidence of hollow heart from 77% to 42%, respectively. Phosphorus had no effect on the incidence of hollow heart.

Increasing nitrogen applications from 60 pounds per acre to 180 pounds reduced the specific gravity of tubers from 1.0862 to 1.0761, whereas it was reduced to 1.0818 with the 120 pound rate. Phosphorus and potassium rates had very little effect on the specific gravity of tubers.

Discussion

Hollow heart in commercial fields has been associated with conditions favoring very active vine growth after tubers have been set. The most common condition observed has been a greatly increased moisture supply following a period of moisture deficiency (6).

As found by others (3, 6, 7, 8, 9, 12, 13, 14) and also in this study, hollow heart is most prevalent in large tubers. This disease is not confined to large tubers as the incipient form has been found by others (8) in small tubers, and, in this study, in tubers as small as 5 grams.

It is interesting to note that increasing the nitrogen applications tended to increase the incidence of hollow heart in both years. However, nitrogen applications in 1959 were more effective in increasing the incidence of the disease than in 1958. Increasing the nitrogen application from 60 pounds to 180 pounds per acre in 1959 increased the incidence of hollow heart from 50 to 73%.

These results are in contrast with those obtained by Button and Hawkins (1) who found that soil and foliar applications of nitrogen did not increase the incidence of hollow heart in the Katahdin variety. It is difficult to explain the conflicting results obtained by others (1, 9, 10). Their experiments were conducted under different soil types and environmental conditions which may account for the differences in results.

It is generally agreed that rapidly growing tops are able to acquire more photosynthates than are the rapidly growing tubers. This may tend to have the same effect as suggested by Krantz and Lana (7) that the active renewal of vegetative growth following defoliation may lead to a temporary nutritional deficiency which initiates the development of the disease.

The increase in the incidence of hollow heart in 1959 as compared with 1958 was probably caused by a greater competition between vine growth and tuber development in 1959 than in 1958. The season in 1958 was warm and dry which tended to restrict vine growth early in the season, and thus counteract the possible stimulative effect of increased applications of nitrogen. Therefore the environmental factors peculiar to the experiment were such that adequate amounts of photosynthates were available to sustain concurrently both vine growth and tuber enlargement. In 1959, with lower temperatures and adequate moisture plus the increased rate of nitrogen, may possibly have stimulated and tended to sustain active vine growth for a longer period of time than in 1958. Longer and more active vine growth, together with a larger set of tubers in 1959, may very likely account for the increased incidence of the disease in 1959.

It is interesting to note that increasing the potassium application from 120 pounds to 360 pounds per acre in 1959 reduced the incidence of hollow heart from 77 to 42%.

Summary

1. The present study was undertaken to determine if the incidence of hollow heart can be influenced in a susceptible variety of potatoes by varying the levels of NPK. This work was done during the years 1958 and 1959.

2. Incidence of hollow heart varied between years. Varying the applications of NPK was more effective in increasing the incidence of hollow heart in 1959 than in 1958.

3. Increasing the nitrogen applications tended to increase the incidence of hollow heart in both years but was more effective in 1959 than in 1958.

4. Increasing the potassium applications in 1959 tended to reduce the incidence of hollow heart.

5. Hollow heart was not influenced by the phosphorus applications used in this study.

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NEWS AND REVIEWS

ABSTRACTS OF PAPERS PRESENTED AT THE FORTY-FOURTH ANNUAL MEETING OF THE POTATO ASSOCIATION OF AMERICA

AMERICAN BAPTIST ASSEMBLY
GREEN LAKE, WISCONSIN

AUGUST 28-31, 1960

BENSON, A. P. AND W. J. HOOKER

CARBOHYDRATE RESERVES IN GRAFTED PLANTS OF VIRUS X RESISTANT VARIETIES

Virus X susceptible but virus X free scions such as potato seedling plants, tomato, or *Datura tatula* L. were grafted to resistant potato stocks of immune S. 41956 or of hypersensitive Epicure and after establishment of graft unions were inoculated with virus X. Starch accumulated in virus X infected scions above the graft union consistently in S. 41956 within 10 to 14 days and to a less pronounced degree in Epicure. Starch accumulated to some extent below the graft union in stocks of both varieties when virus X inoculation of the scion was delayed. Aerial tubers were produced in scions above the S 41956 stocks and occasionally suggestions of aerial tubers were formed above Epicure stocks.

Concentration of reducing carbohydrates and of glucose in roots of S 41956 and Epicure stocks grafted with virus X were considerably lower than that in roots of stocks grafted to scions free from virus X. Similarity of response in grafted Epicure and S 41956 in these trials serves as additional evidence that the mechanism of resistance is essentially similar.

BLOMQUIST, A. W. AND F. I. LAUER

A COMPARISON OF FIRST CLONAL GENERATION POTATO PROGENY PERFORMANCE AT TWO MINNESOTA LOCATIONS

The performance of sixteen first clonal generation progenies involving 850 clones was compared at two Minnesota locations, Red River Valley and Northeastern Minnesota. A single hill of each clone was planted at both locations. Differences between locations were great for most of the characters studied. Significant locations by progeny and location by clone interactions were also obtained. These could be partially attributed to differences in maturity of the parents. The general performance of progenies from early maturing parents was better in the Red River Vally while those from late maturing parents performed better in Northeastern Minnesota.

Seed tuber size greatly influenced subsequent field performance. Though the number of clones selected at both locations was similar the selection of the same clone at the two locations seldom occurred. In most instances, the clone selected at only one location was derived from the larger of the two tubers of each clone that was planted.

BLOMQUIST, A. W. AND F. I. LAUER

A SIMPLIFIED TECHNIQUE FOR THE STORAGE AND HANDLING OF POTATO POLLEN

Other workers have demonstrated that potato pollen can be stored for at least one year. Their procedure for storing pollen includes the collection and drying of whole anthers followed by subsequent storage at low temperatures. This report is concerned with a modification of the above procedure.

Pollen from the variety, Redkote, was collected directly from growing plants in gelatin capsules using a mechanical vibrator. The capsules were stored in glass vials, with and without $CaCl_2$ desiccant, at temperatures of 24°C., 2.5°C. and –24°C. Test pollinations, including a fresh pollen check, were made at intervals for a year on a number of female parents. The pollen remained viable, as indicated by successful

crosses, for eight days when stored at 24°C., for thirty-one days at 2.5°C., and for at least one year when stored at –24°C. Storage with $CaCl_2$ desiccant did not seem to affect viability.

These results indicate that potato pollen collected directly from growing plants can be maintained for at least one year by placing the pollen at –24°C. temperature.

CIPAR, M. S., S. J. PELOQUIN AND R. W. HOUGAS

INCOMPATIBILITY RELATIONSHIPS OF HAPLOIDS FROM *SOLANUM TUBEROSUM* SUBSP. *ANDIGENA*.

Haploids (2n=24) have been obtained from self-fertile clones of *andigena* (2n=48). Two haploids, US-W246 and US-W253 from the *andigena* selection PI230457, are pollen and ovule fertile as determined by their ability to hybridize readily with selections of *S. Phureja* (2n=24). However, all attempts to self the haploids have been unsuccessful. Hybrid seed has been obtained when US-W253, as a pistillate parent, was mated with US-W246, but the reciprocal mating was not succesesful.

It has not been possible to cross either haploid with the *andigena* parent. However, fruit development is initiated and continues for a period of 6-8 days following the haploid x *andigena* mating. The reciprocal mating results in no apparent fruit development. The above results can be explained on the assumption that an incompatibility system of the gametophytic type is operative in these plants.

CORDING, JAMES, JR.

RECENT RESEARCH AND DEVELOPMENT IN POTATO FLAKES

Potato flakes, a discovery of the Eastern Utilization Research and Development Division of the United States Department of Agriculture, were first produced commercially in 1957. During the processing season just ended (October 1959 to June 1960) 45 to 50 million pounds were produced in ten plants in seven states.

As a result of continued research, potato flakes are now made from most major varieties in major growing areas. This has been achieved through modification of the starch in the potato cell by the processing steps of precooking potato slices at 160°F., then cooling them before final cooking to prevent pastiness in the final product, and the addition of emulsifiers to tie up free starch.

These improvements have permitted the use of potatoes of low solids content. They have also permitted flakes to be made in small sizes and to be granulated for use in military field rations where it is believed higher density is needed.

Tests have been made on a pilot plant scale to determine the feasibility of fortification of potato flakes with vitamins. Results show that flakes retain more than 70% of the natural vitamin C of the potato and of added vitamins C and A. These vitamins are retained on storage for at least 7 months in quantities sufficient to provide 50% of the minimum adult daily requirements per serving.

CUNNINGHAM, C. E. AND F. J. STEVENSON

POTATO GENETICS: INHERITANCE OF CHIP COLOR AND DRY MATTER CONTENT

A study of the breeding behavior of 12 parental clones which were classified as high, intermediate, or low based on chip color after cold storage and reconditioning, showed that the behavior of the parental clone was a reasonable estimate of the way it would behave in crosses. Crosses of high x high resulted in the greatest proportion of individuals showing good chip color after storage at 42°F. and reconditioning for 4 weeks at 75° to 80°F. Crosses of low x low gave the smallest proportion of individuals with good chip color. Segregation for chip color and dry matter content appeared to be independent.

DAVIS, C. O. AND ORA SMITH

EFFECTS OF CARBON DIOXIDE ON COOKING AND PROCESSING QUALITY OF POTATOES

Short exposures of potatoes to atmospheres containing high percentages of carbon dioxide prevent or greatly reduce after-cooking darkening in boiled potatoes. It has a similar effect on the occurrence of graying or darkening of oil-blanched or par-fried French fries. This retarding influence persists for 6 to 8 weeks after treatment in subsequent storage at 50°F.

DIONNE, L. A., K. M. GRAHAM AND W. J. HODGSON

THE INHERITANCE OF RESISTANCE TO HIGHER RACES OF *PHYTOPHTHORA INFESTANS*

Resistance to higher races of *P. infestans* (1,2,3,4,5—1,2,3,4,6—1,2,3,4,5,6,) was found to be incompletely dominant. In crosses of immune x susceptible the majority of the hybrids had an intermediate level of resistance and only an occasional plant had a resistance approaching that of the resistant parent.. Intercrossing of the susceptible hybrid progeny yielded various proportions of immunes, depending on the parents used. All immune x susceptible hybrids had a high level of general resistance in laboratory tests. The more susceptible hybrids were equal to or higher in general resistance than the European "field resisters" while the reaction of the more resistant progeny approached immunity. By a system of outcrossing-sibcrossing, the full resistance of *S. demissum* was apparently maintained. This was easily accomplished by overcoming the cytoplasmic male sterility of the *S. demissum* x *S. tuberosum* derivatives through appropriate initial crosses.

FEUSTEL, I. C.

RECENT RESEARCH AND DEVELOPMENT OF FROZEN FRENCH FRIES AND OTHER FROZEN POTATO PRODUCTS

Production of frozen French fries and other frozen potato products has increased steadily from an initial volume of about 3½ million pounds in 1945 to a total of approximately 400 million pounds for 1960. Development of the institutional market, which is now the major outlet for frozen French fries, has been especially rapid. Processing plants are concentrated largely in Idaho, Maine and Washington.

Manufacture of frozen potato patties, puffs, hash brown, diced, mashed, whipped, baked-stuffed and other products is closely associated with the processing of French fries since this offers a means of utilizing small potatoes as well as slivers and short and broken pieces that would otherwise be wasted in French fry cutting operations. New products are being developed from time to time which provide further diversity in processing and contribute to the increasing popularity and ready-to-eat convenience of frozen potato products.

Color and texture are important quality control factors for French fries. Content of reducing sugars in the raw material is less critical for control of product color than in the case of potato chip manufacture. Blanching treatments may be adjusted to control both color and texture within limits. Varieties of potatoes which are consistently high in solids have generally proven best for producing French fries. Potatoes of low solids tend to produce a soggy product and to absorb an excessive amount of fat during frying. Some research effort has been directed toward improving suitability of low solids potatoes for processing.

GRAHAM, K. M., W. A. HODGSON AND L. A. DIONNE

MUTABILITY OF *PHYTOPHTHORA INFESTANS* ON BLIGHT-RESISTANT SELECTIONS OF POTATO AND TOMATO

Two methods were used to select variants of *P. infestans* capable of attacking foliage of resistant selections of potato and tomato. Plants were decapitated and lateral buds were removed when they appeared, to induce giant succulent leaves susceptible to invasion by the fungus. Also, the fungus was cultured on the senescent, yellowing leaves of resistant varieties. After from 10 to 14 days on detached leaves of these types, the fungus sporulated and could be re-inoculated to leaves of a susceptible variety for a secondary build-up. A series of alternate host passages has usually resulted in the appearance of a strain capable of attacking the resistant variety.

The following race shifts were witnessed: 1,2,3,4 to 1,2,3,4 + T_1, 0 to T_1, 1,2,3,4 to 1,2,3,4,6, 1,2,4 to 1,2,3,4 and 1,3,4 to 1,2,3,4. The number of passages required to produce the shift in host range varied with the race and the host.

The presence of a physiological state in senescent or giant leaves which allows growth of the fungus, in combination with the selective effect of "residual" resistance upon the population of fungus nuclei, appears to permit the survival and selection of mutant nuclei.

Mutation to increased virulence, favored by prolonged association with resistant hosts in susceptible phases of their growth cycle may be responsible for the appearance of "new" races of the pathogen in countries where the sexual stage has not been found.

HADDOCK, JAY L.

THE INFLUENCE OF IRRIGATION METHOD, FREQUENCY AND QUANTITY OF WATER APPLICATION ON THE YIELD AND QUALITY OF POTATO TUBERS AND THE NUTRITIONAL STATUS OF THE POTATO PLANT

A complex field-crop rotation experiment in which Russet Burbank potatoes were grown was conducted. Two methods of irrigation, sprinkler and furrow with four soil moisture conditions at each method, were studied.

Fifty per cent more water was required under furrow than under sprinkler irrigation. Yields were significantly higher under sprinkler than under furrow irrigation. Twenty-two to twenty-five inches of supplemental irrigation water were necessary for highest yields of quality tubers.

Data on chemical composition of the potato plant indicate the importance of studying the balance of plant nutrients in the proper appraisal of plant nutritional status. Thomas's "Intensity of Nutrition" and "Quality of Nutrition" factors are shown for the various irrigation regimes.

Irrigation practice exerts a marked influence on the chemical composition, yield and quality of potatoes.

HAWKINS, ARTHUR

METHODS OF SUPPLYING NITROGEN FOR POTATOES

Results of comparisons over a period of several years show that potatoes which received ⅓ to ½ of the applied nitrogen as a sidedressing of urea or ammonium nitrate produced as good yields as did those which received all the nitrogen in the row at time of planting. A total of 150 to 180 pounds of nitrogen per acre was applied.

Comparisons were made at two locations in 1959 of several methods of supplying part of the nitrogen for potatoes. The remainder of the nitrogen was applied in side bands at time of planting.

At one farm, part of the nitrogen (60 lbs. per acre) was applied either as urea, broadcast on rye cover 3 weeks before plowing, or as urea, broadcast after plowing. Significantly better yields were obtained at this location when equal amounts of nitrogen were applied either as cyanamid, 3 weeks before plowing, or as urea, side dressed when the potato plants were 2 to 3 inches high.

At both farms there was no significant difference in yield of potatoes where cyanamid was plowed down and where urea was applied as a sidedressing to supply part of the nitrogen, 60 lbs. per acre. In these comparisons an additional 100 to 120 lbs. of nitrogen per acre was applied in side bands at planting time.

The advantage of sidedressing part of the nitrogen as compared with applying all in the row is discussed.

HODGSON, W. A., L. A. DIONNE AND K. M. GRAHAM

LABORATORY TESTING FOR INTERMEDIATE LEVELS OF RESISTANCE TO PHYTOPHTHORA INFESTANS

The expression of intermediate levels of resistance or "field resistance" in greenhouse-grown potato plants was found to depend upon the concentration of spores used as inoculum. Varieties shown to be highly resistant in field tests were resistant to a higher spore concentration than were moderately resistant or susceptible varieties. Differences in the resistance of varieties which could be correlated with their field reaction were demonstrated in laboratory tests by the inoculation of leaf discs with standardized drops of inoculum containing known spore concentrations. Resistance could be shown to be due to any one or all of three factors: 1) resistance to infection, 2) resistance to invasion of the leaf tissue by the mycelium, and 3) the inhibition of sporulation. Differences in resistance could be demonstrated when either the upper or the lower leaf surface was inoculated.

HOOVER, E. F. AND P. A. XANDER

POTATO COMPOSITION VERSUS **CHIPPING QUALITY**

The role of reducing sugars in the Maillard or browning reaction is well documented in the literature. It has also been absolutely shown that this reaction is a principal cause of the color produced in potato chips during processing. A series of screening studies were undertaken over a two year period to determine if compositional factors of potatoes other than reducing sugars might also be involved in

the browning of potato chips. The results of this work indicated that the only consistent correlation between composition and chipping color was in the occurrence and relative concentration of the monosaccharide reducing sugars glucose and fructose. While it is generally accepted that amino compounds are also directly involved in the Maillard Reaction, no consistent evidence was found that any individual or groups of amino compounds were more active, *in vivo*, in promoting the browning of potato chips than others.

Preliminary work undertaken during the 1959 growing season to examine enzymatic aspects of the synthesis and metabolism of sucrose in potato tubers gave results which suggested correlation between chipping color and the activity level of certain enzymes in the tubers.

The screening studies were carried out largely on a qualitative and semi-qualitative basis. During the present (1960) growing season the compositional studies have been revised and techniques modified to yield data which are more strictly quantitative. Particular attention has been given to the ratios between the activity of enzymes and levels of the major sugar constituents of potatoes, as well as to a number of specific non-sugar compounds reported in the literature to influence the browning or Maillard Reaction.

HOUGAS, R. W. AND S. J. PELOQUIN

INITIAL EVIDENCE CONCERNING THE FEASIBILITY OF POTATO BREEDING AT THE DIPLOID LEVEL

Several prerequisites must be satisfied before the usefulness of haploids (2n=24) of the common potato (2n=48) for potato breeding may be thoroughly explored. The prerequisites include 1) a workable method of extracting haploids from selected tetraploid breeding stocks, 2) stock-piles of haploids derived from a broad genetic base, and 3) usable fertility among the haploid individuals. Progress has been made in fulfilling these prerequisites. Haploids of *S. tuberosum occur* in relatively high frequency among the offspring resulting from *S. tuberosum* (pistillate parent)-*S. phureja* matings. Upward of 500 haploids of the common potato have been isolated to date. These haploid individuals were isolated from 31 different tetraploid parents. The frequency of highly pollen fertile individuals among the "raw" haploids is low. Female fertility, however, is relatively high. Offspring have been obtained from inter-haploid matings and from matings of the haploids with 23 tuber-bearing, diploid *Solanum* species. The success of such matings allow for exploring potato breeding at the diploid level.

HOYMAN, WM. G.

SIGNIFICANCE OF TUBER EYE POSITION TO THE EXPRESSION OF LEAF-ROLL-VIRUS SYMPTOMS BY GREENHOUSE INDEXED POTATOES

Eyes from the stem end, the bud end and the middle of each of 373 leafroll-infected potato tubers were indexed in the greenhouse to determine which produced plants that most reliably expressed leafroll symptoms. Norland, Kennebec and Red Pontiac varieties, and 48 new selections were indexed. All plants from the middle and bud-eyes of 34 Norland tubers produced symptoms.. Only 21 stem-end eyes produced plants with symptoms; 11 failed to grow and 2 produced apparently normal plants. In the 21 instances where each tuber produced 3 plants, the symptoms were more distinct in plants from the middle and bud-end eyes.

All the middle and bud-end plants from 25 Red Pontiac tubers showed symptoms. Ten stem-end eyes failed to grow and 4 plants from such eyes expressed no symptoms. In 5 of the 11 instances where each tuber produced 3 plants, the middle and bud-end plants had commensurate but more distinct symptoms than plants from the stem end.

All the bud-end and 45 of the middle eyes of the 46 Kennebec tubers produced leafroll plants. Fifteen of the stem-end eyes failed to grow and 3 plants from this position expressed no symptoms. Twenty-eight tubers produced plants from all 3 positions and the degree of leafroll expression between plants from the stem end and the other 2 positions was greater in this variety than in Norland and Red Pontiac. Nineteen bud-end and 17 plants from the middle eyes expressed more marked symptoms than plants from the stem end.

The data obtained from the 48 selections were similar to those from the 3 varieties.

The leafroll reading was made 44 days after the eyes were planted.

IRITANI, W. M.

EFFECTS OF IRRADIATION ON STORAGE QUALITIES OF RUSSET BURBANK POTATOES

Gamma ray irradiation from atomic fission product wastes was seriously considered at one time and still is considered to some extent as a possible means of sprout inhibition of potatoes. The University of Idaho, Arberdeen Branch Experiment Station has been conducting work of this nature since 1955.

The data from 10-pound bags and individual tubers revealed that a treatment of approximately 10 kiloreps had the least weight loss due to sprouts, rot, irradiation tion, and respiration. Low temperature storage was more effective than irradiation in preventing losses. The data from the bagged tubers revealed that if treatment was deferred until after breaking of dormancy the weight loss was sharply reduced. This finding, however, was not substantiated by the individual tuber data. Generally the tubers lost the most weight from respiration and transpiration the first month in storage after treatment.

Although the data were not consistent it appears that dry matter content decreases with increased dosages of irradiation. Also, on the average the earlier treated potatoes had higher dry matter conetnt. This, however, may not be a time of treatment effect. Generally, the dry matter seems to increase with length of storage period. The dry matter, on the average, was higher for higher storage temperature.

JOHNSTON, G. R. AND R. G. ROWBERRY

A STUDY OF THE TUBER SIZING AND ACCUMULATION OF TOTAL SOLIDS' CONTENT OF SEVERAL VARIETIES OF POTATOES HARVESTED WEEKLY DURING THE GROWING SEASON OF 1957-1959

Harvesting of replicated plots of each variety was commenced each year in mid-July and continued until mid-September. Numbers of tubers 1⅞ inches and over per plot were recorded and specific gravity determinations were made within 24 hours on the tuber samples. Yields in bushels per acre were calculated on a perfect stand basis and per cent total solids obtained from the specific gravity readings using Von Scheele's formula

All varieties in all three years, with the exception of those classed as very late maturing (Sebago and Huron) attained a maximum total solids' percentage by mid-August under Ontario growing conditions. The numbers of marketable size tubers (1⅞ inches and over) was also near maximum by this date. In many cases there was a decrease in per cent total solids for a number of the varieties harvested in late August and September. However, in general, the yield of marketable tubers continued to increase to the mid-September harvesting date. It is suggested that, except for very late maturing varieties of potatoes, the yield increase is mainly due to an increase in the size of already marketable tubers rather than to an increase in the numbers of these. This increase in yield has been shown to be often accompanied by a decrease in the total solids' percentage.

KOLLMER, G. F. AND R. H. LARSON

HOST RANGE, PROPERTIES, VARIETAL REACTION AND RESISTANCE IN RELATION TO ISOLATES OF POTATO VIRUS F

Several isolates of potato virus F exhibited similarities in their potential to infect a wide range of plants. On most plants one of the isolates could definitely be distinguished from the other by a much faster and more severe reaction. In certain American potato varieties, on sap inoculation at 18°-20°C., 3 of the isolates incited a severe top necrotic reaction, whereas 4 isolates systemically induced only a mosaic pattern with some necrotic spotting. The presently known host range of potato virus F was extended; two varieties of crimson clover (*Trifolium incarnatum*), and 3 varieties of subterranean clover (*Trifolium subterranean*) being the most significant. Resistance to virus F was found in the species *Solanum chacoense*, and in several interspecific hybrids involving *Solanum chacoense*. Physical properties of the virus F isolates were determined using freshly extracted juice of recently infected young Samsun tobacco plants as infective material. The thermal inactivation point was found to be between 65° and 70°C., the longevity *in vitro* up to 90 days, and dilution end point between 1:100,000 and 1:1,000,000.

NORTVEDT, J. J., M. H. FLEISCHFRESSER, K. C. BERGER AND H. M. DARLING

THE RELATION OF SOLUBLE MANGANESE TO THE INCIDENCE OF COMMON SCAB IN POTATOES

Levels of soluble manganese ranging from 0 to 20 parts per million were added to white quartz sand in the tuber forming zone of two scab susceptible varieties of potatoes. The roots extended into a complete nutrient solution in a two gallon jar placed below the sand container. Cultures of *Streptomyces scabies* were added to the sand. The scab index decreased as manganese concentrations were increased. Tissue analyses showed increased uptake of manganese with increased application in the tuber zone, even though the manganese concentration in the root zone was constant.

These results indicate that high manganese concentrations in the soil solution may be one of the factors why scab is less prevalent in highly acid soils.

PELOQUIN, S. J., R. W. HOUGAS AND A. C. GABERT

THE FREQUENCY OF HAPLOIDS IN *SOLANUM TUBEROSUM*

Methods of markedly increasing the frequency of haploids are essential if large numbers or haploids are to be accumulated expeditiously. Twelve varieties and 21 "pollinators" were used in attempts to determine the effect of the pistillate parent and the "pollinator" on the frequency of haploids obtained through interspecific matings. The choice of the *S. tuberosum* parent had a very significant effect on the haploid frequency. The varieties Merrimack and Tawa were the best of the 12 tested. A quite unexpected result was the highly significant effect of the "pollinator" on the frequency of haploids. One selection of *S. phureja*, P1225682, was approximately 10 times more effective than any of the other "pollinators" employed. Similar results have been obtained when this "pollinator" was used with selections of *S. tuberosum* subsp. *andigena* as the pistillate parent. The choice of the "pollinator", therefore, appears to be a simple and effective means of increasing the frequency of haploids obtained from many varieties of *S. tuberosum*.

PICHA, BEN

ERLIRED, A NEW RED-SKINNED POTATO VARIETY WITH HIGH RED COLOR, MARKET ATTRACTIVENESS, EARLINESS AND EASY TO GROW AND HANDLE

Six years of experiment station trials combined with commercial grower testing gives the assurance that Selection 50.4-52-40 merits introduction as a named variety. This selection was tested in North Dakota, Minnesota, Oregon, Ohio, Utah and Colorado. The cross was made in 1950 between two seedling selections 43.23-6 x 43-17-16. No. 43.23-6 was derived by crossing the Early Ohio with 44537 and No. 43-17-16 was from 528-170 x Minn. 15. The plants are erect, medium in size and developed rapidly with a set of 5 to 9 tubers. Important characteristics are the high-red color skin, market attractiveness, early maturity, maintainance of shapeliness and freedom from growth cracks, knobs and hollowheart. Specific gravity is equal to Triumphs, Waseca and Norland. It has moderate scab resistance, no resistance to late blight and viruses remain untested.

PLAISTED R. L., LIND SANFORD, W. T. FEDERER, A. E. KEHR AND L. C. PETERSON

ESTIMATES OF COMBINING ABILITY OF POTATO CLONES

To conduct a breeding program for yield improvement, whether by inbreeding or recurrent selection, requires the use of test crosses to identify individuals with superior combining ability. The research reported in this paper provides information on the conduct of such testcross trials.

In 1956 crosses were made between 45 breeding lines and 6 tester parents; 190 of these were successful. These were grown as seedling hills in 1957. At harvest time, the hills within progenies were bulked and provided seed for yield trials conducted in 1958 at Clear Lake, Iowa; Riverhead, New York and Ithaca, New York. These trials included the 190 bulked testcross progenies and ten check varieties planted in a rectangular lattice design with 6 replications. All the analyses reported in this paper are based on total yields per ten-foot plot.

The data have been analyzed to compare the relative magnitude of the components of variance attributable to general and specific combining ability. Estimates of the general combining ability effects of each of the lines have been obtained. The interaction of general combining ability effects with locations is compared with the interaction of specific combining ability effects with locations. Estimates of the optimum number of testers required to adequately measure general combining ability are presented.

POTTERTON, P. E., K. C. BERGER AND E. L. HOBSON

INFLUENCE OF CHLORIDES AND SULFATES IN POTATO FERTILIZERS ON THE PHOSPHORUS UPTAKE, YIELD, AND QUALITY OF POTATOES

The influence of chlorides and sulfates in potato fertilizers on the phosphorus uptake and the resulting effect on the yield and quality of potatoes was studied in the field and greenhouse over a four-year period.

Chlorides, as the potassium salt, when banded in the row with phosphates, depress phosphorus uptake and dry matter contents of the tubers when compared with sulfates at equivalent potassium rates. When chlorides are applied broadcast with all of the phosphate and small amounts of potassium sulfate banded in the row, this effect tends to be eliminated.

Removing all potassium from the row-starter fertilizer results in uneven early growth and very dark green vines.

Potato plants receiving chlorides have relatively large, thin, light green colored leaflets and somewhat taller vines. Plants receiving sulfate have smaller, thicker, very much darker green colored leaflets and somewhat sturdier stems.

The fertilizer treatments giving highest yields and highest dry matter contents of the tuber were the broadcast application of 300 to 800 pounds per acre of potassium sulfate or chloride together with the row application of 500 to 700 pounds of 10-35-5 fertilizer containing sulfate of potash or sulfate or potash-magnesia.

When available magnesium was deficient, best yields and quality were obtained with the use of sulfate of potash-magnesia both the row and broadcast application of potash.

RICH, A. E., C. S. CAMPBELL, R. E. MULLANY, F. E. MANZER AND P. T. BLOOD

THE INFLUENCE OF VARIOUS FUNGICIDES AND ANTIBIOTICS ON CUT SEED POTATOES

Potato seed pieces, treated with captan, maneb, dichlone, ziram or zineb, either as an instant dip or a dust, were protected from Fusarium seedpiece decay when planted in inoculated soil in the greenhouse. Nabam, Agrimycin, Filipin, Griseofulvin, Mycostatin, Oligomycin, Rimocidin, Semesan Bel and streptomycin sulfate were either ineffective for control of Fusarium seedpiece decay or injurious to potato seed pieces or both. Agrimycin reduced the effectiveness of both captan and maneb when combined with them.

Seed potatoes, cut and suberized in Maine during the winter months and shipped to New Hampshire for spring planting, usually produced satisfactory stands and yields without any fungicidal or antibiotic treatment. However, a captan dip, either before or after cutting, reduced the surface molds and improved the appearance. Seed pieces treated with Agrimycin or with captan plus Agrimycin developed more surface mold and partial decay than pieces treated with captan alone. However, this fungus growth did not usually significantly reduce either stands or yields.

SCHULTZ, T. H., K. C. BERGER, H. M. DARLING, AND M. H. FLEISCHFRESSER

UREA FORMALDEHYDE CONCENTRATE-85 FOR SCAB CONTROL IN POTATOES

Field experiments were conducted using Urea Formaldehyde Concentrate-85 (UFC-85) in row and broadcast applications for scab control of potatoes in 1958 and 1959. This material is a polymethylol urea composed of approximately 26% urea and 60% formaldehyde and having a urea-to-formaldehyde mole ratio of 0.217. UFC-85 tends to release formaldehyde slowly and contains about 1 pound of nitrogen per gallon. The material was applied in the row at planting, in a 12 inch band at rates of 10 to 80 gal per acre and broadcast at rates of 75 to 150 gal per acre.

Three experiments in 1958 and 11 experiments in 1959 were conducted on either sand, sandy loam, silt loam, or peat soils. Row application of 10 and 20 gal of UFC-85 per acre reduced scab somewhat but did not give desired control. No delay in emergence or reduction in stand was evident. Row application of 30 to 40 gal per acre did not affect germination and no phytotoxicity occurred. Emergence was slightly delayed, but scab control was excellent. All rates above 40 gal per acre improved potato scab control but was accompanied by a slight reduction in stand and delayed emergence. Broadcast treatments of 100 and 150 gal per acre also gave excellent scab control.

SMITH, ORA

RECENT RESEARCH AND DEVELOPMENT OF POTATO CHIP PROCESSING

The following phases of potato chip processing and production of raw material for processing will be discussed:

1. Cultural conditions that affect processing quality of potatoes—specific gravity and sugar content.
2. Spraying plants with chelating and sequestering chemicals.
3. Preventing or delaying sugar development in potatoes by treating with various gases
4. Preventing dark color development in chips with chemical treatment of slices.
5. Developing rapid methods of predetermining chip color.
6. Blistering of potato chips.

SMITH, ORA AND C. O. DAVIS

PREVENTING DISCOLORATION IN COOKED AND FRENCH FRY POTATOES

After-cooking darkening of boiled potatoes may be completely prevented by additions of very low concentrations of sodium acid pyrophosphate to the water in which they are boiled. Whiteness of the entire potato is accentuated and the usual ivory or yellowish color of the potato is prevented from forming

Graying and darkening of oil-blanched or par-fried French fries also is prevented by blanching the cuts in hot water to which sodium acid pyrophosphate has been added.

SMITH, W. L., JR.

LOW TEMPERATURE STORAGE EFFECTS ON BARRIER DEVELOPMENT AND DECAY OF POTATOES

Irish Cobbler tubers developed severe pitting and shrinkage within 1 to 2 months' storage at 32°F. Slices from these tubers held in moist chambers at 70° developed less suberin and periderm and were more susceptible to decay by *Erwinia carotovora* than slices from tubers stored at 34°, 40°, or 55°. Late season Katahdin tubers stored at 32° or 34° had severe pitting and shrinkage within 2 months. Slices from 32° tubers developed barriers slower at 70° and had more decay by *Erwinia carotovora* than slices from tubers held at 34°, 40°, 50°, or 55°. After 3 months' storage almost all of the Katahdin tubers examined from the 32° or 34° storage had mahogany browning. Slices from tubers from these temperatures developed less barriers at 70° and were more susceptible to decay than slices from tubers stored at 40°, 50°, or 55°. Holding tubers from 32° or 34° for 1 week at 70° did not increase barrier development or decrease decay of the slices. A high percentage of the reconditioned tubers from 32° or 34° had blackheart. After 2 months Irish Cobbler tubers at 32°, and after 3 months Katahdin tubers at 32° or 34° were heavily infected with *Penicillium* sps. Slices of these tubers were rapidly decayed by *Rhizopus* and *Penicillium* sps. Neither of these organisms infected slices from tubers held at higher temperatures. The studies show that if storage temperatures as low as 32° or 34° are used for 2 months or longer, low temperature damage during storage may be one of the main causes of seed piece decay.

STEVENSON, F. J. AND C. E. CUNNINGHAM

CHIP COLOR IN RELATION TO POTATO STORAGE

Chips with excellent color can be made from hundreds of varieties directly after harvest if the potatoes are grown and handled properly. However, there are differ-

ences among these varieties in their responses to various storage conditions.. Chips with excellent color can be made from many varieties direct from 3 to 4 months storage at 50°F. When stored at either 42° or 38°, from 3 to 4 months, chips with marketable color could not be made from any of the tubers direct from storage. However, the varieties differed greatly in their responses to reconditioning at 75° to 80°. The chips of a few varieties possessed marketable color 2 weeks after removal from either 42° or 38°. Other varieties reconditioned in 3 weeks, still others in 4 weeks but some did not recondition in 7 weeks.

STEVENSON, F. J. AND C. E. CUNNINGHAM
POTATO VARIETY TRIALS

Potato variety trials are being made on the Red Dot Farms in Wisconsin and Alabama. The research program is designed to breed varieties superior to the standard varieties in chip quality, yield, specific gravity, season of maturity, resistance to disease, response to various fertilizer treatments and other characters. The data in the paper show some of the results that have been obtained with special emphasis on varietal behavior in various environmental conditions.

TOKÔ, H. V.
THE EFFECT OF VENTILATION RATES ON THE KEEPING QUALITY OF STORED POTATOES

Studies have been conducted over the past 3 years to determine the effect of different ventilation rates on the development of storage rots in potatoes affected with known diseases or injuries at the time of storage. Using air flow rates of 0, 0.5, 1, 1.5, cfm per barrel (0, 0.3, 0.6, 0.9 cfm per cwt.) weight loss in sound samples average 2.2, 2.7, 3.8 and 3.4 per cent, respectively, from the lowest to the highest air flow rates. Samples containing 20% by weight of frozen potatoes were placed at the ⅓ and ⅔ full level of 12 foot deep bins receiving the different ventilation rates. It was found that as the ventilation rate increased, secondary infection of potatoes by soft rot decreased. Total loss of sound tubers, due to weight loss, (mostly moisture) and disease, in the samples averaged 16.9, 16.3, 12.4 and 9.4%, respectively, in the bins receiving the lowest to the highest air flow rates for the 1957-1958 and 1958-1959 storage season. Due to a high degree of incipient infection by late blight, the differences in sound tubers were apparent but not so marked in the 1959-1960 storage season. An apparent layering effect was noted at the 2 highest ventilation rates used. In the samples located at the ⅓ level from the bottom, weight loss (including loss from soft rot) of sound tubers was 8.8 and 7.6% at 1 and 1.5 cmf, respectively, whereas at the ⅔ level the loss of sound tubers was 16.1 and 11.3%.

TREADWAY, R. H.
RECENT RESEARCH AND DEVELOPMENT IN POTATO FLOUR AND POTATO STARCH

Potato Flour. Potato bread, containing 2-6% potato flour (based on the weight of wheat flour), has been the principal individual outlet for potato flour. Recently, potato crackers containing 15-20% potato flour have gained wide popularity and now constitute another important market for potato flour. The quantity of potatoes consumed in making flour has increased from 930,000 hundredweightts in 1953 to 2,220,000 hundredweights in 1959. This increase in demand is generally credited to the development of potato crackers by the industry and to the improvement in the quality of potato flour for bread.

Potato Starch. Productive capacity of the country is about equally divided between the Maine and Western states' plants, and a total annual production of 150 million pounds is considered to be a good figure. A new potato starch plant being built at Houlton, Maine, is attracting the most attention at present. This plant will have the capacity for grinding about 8,250 hundredweights of potatoes daily. A complete line of modified starches, that is dextrins, thin-boiling starches, and oxidized starches will be made by conversion of the potato starch. The American potato starch industry also plans to make hydroxyethyl starch, a chemical derivative. This derivative performs well in the warp sizing of synthetic textiles. Potato starch continues to be preferred as the base for "instant desserts".

WILCOX, GERALD E.

EFFECT OF CHLORIDE AND SULFATE SOURCES OF FERTILIZER ON POTATO GROWTH AND TUBER QUALITY IN SOUTHWESTERN INDIANA

Broadcast applications of potassium to a soil that contained 161 pounds of potassium did not affect the yield or specific gravity of potatoes over the range of 0 to 225 pounds K_2O per acre. Nitrogen rates over the range of 32 to 164 pounds per acre did not affect either the yield or quality of the Kennebec potatoes. Leaf samples collected at the pre-bloom stage of plant development showed that their calcium and magnesium compositions were lower for the sulfate treated plots. The chloride treated plots yielded potatoes that chipped lighter in color.

WILLIS, C. B. AND R. H. LARSON

A NEW HOST FOR POTATO VIRUS X IN THE LEGUMINOSAE

Crimson clover, *Trifolium incarnatum*, has been shown to be a host for both the ringspot and yellow strains of potato virus X. The two strains have been recovered unchanged after 4 months from systemically infected leaves of the varieties Chief and Dixie. At 18°-20°C. the primary symptoms are seen after 12-14 days as slight interveinal chlorosis followed by a well defined veinal necrosis which increases to involve the entire leaf. Systemic symptoms are evident after 4-5 weeks as a slight interveinal mottle which intensifies to become chlorotic. This is followed by pronounced veinal necrosis. A field strain of potato virus X from the variety Green Mountain also systemically infected the two varieties of crimson clover.

MANZER, F. E. AND DONALD MERRIAM

FIELD TRANSMISSION OF THE POTATO SPINDLE TUBER VIRUS AND VIRUS X BY CULTIVATING AND HILLING EQUIPMENT

Studies conducted over the past three years have shown that the spindle tuber virus and virus X can be disseminated very readily in potato fields by contact of healthy vines with contaminated cultivating and hilling equipment. Nearly 100 per cent transmission of each virus was recorded in the Katahdin and Kennebec varieties in tests which simulated excessive contact of large vines with contaminated equipment. Under conditions of less severe vine contact a lesser amount of transmission of each virus was observed. When cultivation and hilling operations were performed before vines were large very little transmission of either virus was obtained. .

Cultivating and hilling equipment contaminated with the spindle tuber virus was used to inoculate nine potato varieties to observe differences in susceptibility. Transmission percentages among varieties ranged from 31 to 65%.

Greenhouse readings of indexed samples from the spindle tuber dissemination studies showed very close agreement with field readings.

These studies have shown that early cultivation and hilling are essential when potato seed stocks are known to contain the spindle tuber virus or virus X.

YOUNG, DONALD A.

SAMPLING OF POTATO TUBER POPULATIONS FOR DRY MATTER ASSESSMENT

The specific gravity of approximately 9,000 potato tubers was determined by the brine flotation method. Standard deviations of individual populations ranged from .0040 to .0086. Assuming an error due to chance of 1 in 20, and a maximum standard deviation of .01000, sample sizes were calculated for various degrees of accuracy. For an estimate of dry matter content, within 1% of the population mean, a sample of 16 tubers was required; within ½% dry matter, 60 tubers; within ¼% dry matter, 191 tubers and within ⅛% dry matter, 999 tubers were required. An experienced taste panel could, wth statistical accuracy, differentiate between samples of tubers within varieties, which differ by 1% dry matter. .

SAWYER, RICHARD L.

SOME CONSIDERATIONS ON PROCESSING PLANT LOCATION

All potato areas large and small are trying to lure potato processors. Processors are giving serious consideration to all areas of production for plant placement. The

processors needs are quite specific. Most areas have advantages and disadvantages. Factors such as variety of potato, climate of the area, storage facilities, concentration of production, cost of production, spread between research knowledge and grower application are some of the important considerations

SMITH, W. L., JR. AND R. V. AKELEY

STORAGE, TRANSIT, AND PLANTING TESTS WITH PRECUT SEED POTATOES

When freshly cut potato seed pieces were stored for 2, 5 or 7 months at 40° or 50°F., Plymouth seed pieces usually developed considerably more decay than those of Sebago or Pungo, and Kennebec seed pieces considerably less. Plymouth and Sebago seed pieces developed more decay than the other varieties when held at 40° or 50° for 10 days before planting.. In most cases approximately the same percentage decay developed at 40° and 50°. Suberization of seed pieces for 1 week at 60° before storing at 40° and 50° usually reduced decay considerably. Decay was caused mostly by Fusaria and soft rot bacteria.

When sound Kennebec, Pungo, or Sebago seed pieces were planted after 7 months' storage and compared with those cut 10 days before planting, and with freshly cut, and "B" size (uncut) potatoes, little difference in stand or yield between seed piece treatments of the respective varieties resulted.

Irish Cobbler seed pieces with a relatively high incidence of decay after 8 days of transit were held at 40°, 45°, 50°, 55°,, and 60°F. for 6 weeks before planting. The highest percentage decay (mostly *Fusaria*) developed on seed pieces held at 60° and the lowest on those held at 40°. Seed pieces held at 50°, 55°, or 60° had excessively long sprouts. Stands and yields from sound seed pieces from each temperature were approximately the same as freshly cut seed pieces or uncut "B" size potatoes from the same temperatures. Precut Irish Cobbler seed pieces planted immediately after shipment had higher yields than those held 6 weeks before planting.

DARLING, H. M., AND R. V. AKELEY

RESISTANCE TO POTATO ROT NEMATODE

From May to November, 1959, 43 U.S.D.A. potato seedlings were grown in the greenhouse in 8-inch pots filled with soil infested with potato rot nematodes (Ditylenchus destructor). Eight seedlings appeared to be resistant, but later microscopic examination showed that 2 of these were susceptible. Seven of the 8 seedlings and 3 parents were planted again in January and harvested June, 1960. Three parents, B 3097-82, B 3139-24, and B 3309-8, proved to be resistant and 5 of the 6 originally resistant seedlings again showed resistance. Seedling B 4312-4, a cross of B 3309-8 x B 3139-24, was one of the 5 better resistant seedlings tested twice and found resistant.

HONORARY LIFE MEMBERS

Dr. Ora Smith, of Cornell University; Dr. Russel Larson, of the University of Wisconsin; and Mr. Ben Picha, of Grands Forks, Minnesota were made Honorary Life Members of the Potato Association of America at the 44th annual meeting in Green Lake, Wisconsin in recognition of their outstanding service to the potato industry.

Dr. Smith is internationally known for his research work in potato production and processing. Dr. Larson is widely known for his work with potato viruses and Mr. Picha for his potato breeding activities and leadership in potato production methods.

A more complete report of this event will be published in the November issue.

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